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ROBOTICS ENGINEERING

THE JOURNAL OF INTELLIGENT MACHINES

End-of-Arm Tooling
Material Handling

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EDITORIAL

FEATURES

DEPARTMENTS

About the cover: This month's cover photo, provided by Gould/International Cybernetics, depicts a robotic stamping press loader/unloader made by Schuler, Inc. of Columbus, Ohio. The production line, consisting of six loader/unloaders, one transfer/turnover device, and four transport units, is controlled by a Gould/ICC Model 3220 Flexible Automation Controller. See related product application feature on page 26.

Editorial

Anthropomorphism And Efficiency

BY CARL HELMERS

We recently came across an article by Warren Seering, "Building Robots in the Image of Machines" (*MIT Technology Review*, April 1985). Readers who have not seen this issue should obtain a copy, for the article makes an essential and important point: machines should be optimized as machines, not necessarily using anthropomorphic models. The systems we design should accomplish their engineering goals independent of preconceptions about the particular implementation technology that might be used. Seering's point is that just because humans use a certain order and sequence of operations when assembling something or accomplishing some other task, it does not necessarily follow that a robot should be designed to carry out its tasks in the same way a human does.

The human being is marvelously adaptable—able to perceive with many built-in sensory systems, able to reason, and endowed with a set of quite generalized manipulators. The human being is also endowed with colds, emotions (including humor and curiosity), and a certain perverse randomness of performance. These characteristics make the human–machine interface the focus of an entire specialized field of engineering.

A robotic manufacturing system is not necessarily a machine that should be given anthropomorphic characteristics. Calling robotic manipulators "arms" and using the human model in other respects may, in fact, be dangerous. A robotic machine is a machine and not a co-worker that one can shake hands with. It is a piece of equipment operated by people, not one of the guys. The automatic manufacturing environment is not one into which humans should wander during operations, any more than we'd expect people to put their fingers into a lathe, punch press, mill, or any other potentially dangerous machines.

Seering's article emphasized that a generalized multiple joint model of the human arm anatomy might be a poor choice for use on a robotic mechanism. Aside from the safety issue, there are the mechanical engineering considerations. Each additional joint adds additional sources of mechanical error. Each additional joint adds weight to bend and stress the "arm." Each additional joint adds complexity to the kinematics the software uses to drive the arm. Simpler, less expensive assembly robots, coupled with greater attention to design for automatic assembly, might be the most effective approach to flexible automation.

Which brings us to a theme of this issue—end effectors. Use of the technical term, "end effector," instead of "robotic hand" implicitly distinguishes the robotic from the anthropomorphic, the machine from the human. The human-like "hand-picking-up-tool" concept is frought with compromises, and the root of the problem is the anthropomorphic model. Interchangeable end-of-arm tooling is appropriate for some applications. For robotic installations using simpler manipulators (lower compound position error through use of fewer joints), the carousel approach is feasible. The time a multi-jointed arm robot requires to reach its tool box must be traded off against the extra weight of a carousel carried on the arm.

In one robotic installation we have toured, a hard disk coating line, very expensive general purpose manipulators with relatively light weight carousel style end effectors were used. As anthropomorphic arms, the manipulators simulated the actions of two very busy mobile one-armed workers picking up disks, moving them to the coating machines, and then removing them for drying and other downstream operations.

The carousel approach to handling multiple workpieces in a transfer operation worked extremely well, according to our hosts. However, they said that in their next robotic automation application, a much simpler manipulator would be used, one with fewer degrees of freedom. In this case, the general purpose multiple jointed arm will give way to a simpler design as the real needs of the application are determined. The carousel end effector, a specialized non anthropomorphic device, will likely be retained for moving the disks down the production line.

Seering's point, that the human body is not necessarily the optimal model for machine design, should be taken as one input in all our designs. End effectors are no exception. ■

Calendar

FEBRUARY

4–6. 7th International Conference on Assembly Automation. Zurich, Switzerland. Contact: Conference Manager (ICAA-7), IFS (Conferences) Ltd., 35–39 High St., Kempston, Bedford MK42 7BT, England, telephone (0234) 853605.

11–13. Orlando Manufacturing Productivity Conference and Exposition. Orlando Expo Centre, Orlando, FL. Contact: Society of Manufacturing Engineers, One SME Dr., PO Box 930, Dearborn, MI 48121.

25–27. Automatic Guided Vehicle Systems. Advanced Manufacturing Systems—Engineering Group, Norcross-Atlanta, GA. Contact: Diane Korona, Program Administrator, Special Programs Division, Society of Manufacturing Engineers, One SME Dr., PO Box 930, Dearborn, MI 48121, telephone (313) 271-1500, ext. 392.

26–28. Robotics for the 21st Century. Atlanta Hilton and Towers, Atlanta, GA. Contact: Trish Stolton, Dept. of Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332-0385, telephone (404) 894-2547.

MARCH

3–5. Robotics Seminar. IIE Education Center, Atlanta, GA. Contact: Institute of Industrial Engineers, 25 Technology Park, Atlanta-Norcross, GA 30092, telephone (404) 449-0460.

3–6. Flexible Manufacturing Systems. Hyatt Regency O'Hare, Rosemont, IL. Contact: John McEachran, Special Programs Division, Society of Manufacturing Engineers, One SME Dr., PO Box 930, Dearborn, MI 48121, telephone (313) 271-1500.

3–6. Agri-Mation 2 Conference and Exposition. Chicago Hilton & Towers, Chicago, IL. Contact: Public Relations Department, Society of Manufacturing Engineers, One SME Dr., PO Box 930, Dearborn, MI 48121, telephone (313) 271-0777.

5–7. Expert Systems. Doubletree Inn, Monterey, CA. Contact: Continuing Education Institute, 10889 Wilshire Blvd., Los Angeles, CA 90024, telephone (213) 824-9545. (To be repeated **19–21 March** at Holiday Inn, Government Center, Boston, MA; and **2–4 April** at Amfac Hotel, Los Angeles, CA.)

6–7. IBM CAD/CAM Strategies; Using Personal Computer-based CAD/CAM Systems in Large Organizations; and How to Buy Your Second CAD/CAM System. (Three workshops). Westgate Hotel, San Diego, CA. Contact: CAD/CAM Publishing, Inc., 841 Turquoise St., Suite D, San Diego, CA 92109, telephone (619) 488-0533.

12–14. Artificial Intelligence for the Automotive Industry. Westin Hotel, Detroit, MI. Contact: Dale Mason, SME Technical Activities Dept., Computer and Automated Systems Association of SME, One SME Dr., PO Box 930, Dearborn, MI 48121, telephone (313) 271-1500, ext. 375.

17–19. Interactive Analysis: Dynamic Feedback Systems. Amfac Hotel, Los Angeles, CA. Contact: Continuing Education Institute, 10889 Wilshire Blvd., Los Angeles, CA 90024, telephone (213) 824-9545. (To be repeated **7–9 April** at Ramada, Oxon Hill, MD.)

17–20. WESTEC '86. Los Angeles Convention Center, Los Angeles, CA. Contact: Society of Manufacturing Engineers, One SME Drive, PO Box 930, Dearborn, MI 48121, telephone, (313) 271-0023, ext. 328.

17–21. Internet Systems and Protocols. Contact: Dick White, The George Washington University, Washington, DC 20052, telephone (202) 676-6106 or (800) 424-9773.

Calendar

18–21. International Handling & Storage Exhibition—IHSE '86. National Exhibition Centre, Birmingham, England. Contact: Keith Harris, Trinity Publishing Ltd., Station Approach, Long Lane, Hillingdon, Middlesex UB10 9NR, England.

19–21. 3rd International Conference on Automated Materials Handling. Metropole Hotel, National Exhibition Centre, Birmingham, England. Contact: IFS (Conferences) Ltd., 35–39 High St., Kempston, Bedford MK42 7BT, England, telephone (0234) 853605.

24–26. SYSTEMS™ 1, For Integration of Plant Automation Communications and Control. Chicago Hilton & Towers, Chicago, IL. Contact: Paul Borawski, Assistant Manager, Technical Activities, Society of Manufacturing Engineers, One SME Dr., PO Box 930, Dearborn, MI 48121, telephone (313) 271-1500.

24–27. DEPO 86. McCormick Place, Chicago, IL. Contact: Show Manager, DEPO 86, 999 Summer St., Stamford, CT 06905, telephone (203) 964-8287.

26–28. Local Area Data Communications Networks. Contact: Shirley Forlenzo, The George Washington University, Washington, DC 20052, telephone (202) 676-6106 or (800) 424-9773.

APRIL

1–3. Manufacturing Productivity Conference and Exposition. H. Roe Bartle Hall, Kansas City, MO. Contact: Public Relations Department, Society of Manufacturing Engineers, One SME Dr., PO Box 930, Dearborn, MI 48121, telephone (313) 271-0777.

3–4. Artificial Intelligence—An Applications-Oriented Approach. Contact: Stod Cortelyou, The George Washington University, Washington, DC 20052, telephone (202) 676-6106 or (800) 424-9773.

7–10. 1986 IEEE International Conference on Robotics and Automation. San Francisco Hilton & Tower, San Francisco, CA. Contact: Robotics & Automation, c/o Harry Hayman, 738 Whitaker Terrace, Silver Spring, MD 20901, telephone (301) 434-1990.

8–10. Instrumentation '86—Pacific Northwest Conference and Exhibit. Red Lion Inn, Lloyd Center, Portland, OR. Contact: Duane Schroeder, Publicity Chairman, Control Elements, Inc., 1730 S.W. Skyline Blvd., Portland, OR 97221, telephone (503) 297-1533.

8–10. 1986 Test & Measurement World Expo. San Jose Convention Center, San Jose, CA. Contact: Meg Bowen, Conference Director, Test & Measurement World Expo, 199 Wells Ave., Newton, MA 02159, telephone (617) 964-8900.

8–10. 15th Annual International Programmable Controllers Conference and Exposition. Cobo Hall, Detroit, MI. Contact: Carmelita Smirnes, Media Relations Coordinator, Engineering Society of Detroit, 100 Farnsworth Ave., Detroit, MI 48202, telephone (313) 832-5400.

9–16. Industrial Automation '86. Independent exhibit sector of Hannover Fair '86, Hannover, West Germany. Contact: Hannover Fairs USA Inc., PO Box 7066, 103 Carnegie Center, Princeton, NJ 08540, telephone (609) 987-1202.

21–24. ROBOTS '86. McCormick Place, Chicago, IL. Contact: Robotic Industries Association, PO Box 1366, Dearborn, MI 48121, telephone (313) 271-7800.

22–24. Quality Expo TIME. O'Hare Expo Center, Rosemont, IL. Contact: Quality Expo TIME, 2400 E. Devon Ave., Suite 205, Des Plaines, IL 60018, telephone (800) 323-5155 (in IL, (312) 299-3131).

An Overview of Vacuum and Gripper End Effectors

Ron Micallef
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End-of-arm tooling is one of the most important considerations for robot parts handling. This is the device that will grip or secure the part or product. It is imperative that the correct tooling be selected, tooling that suits the part or product need and is compatible with the robot's handling capabilities. Often, the tooling is overlooked until the robot has been purchased and the end effector style is thus compromised. End-of-arm tooling can generally be put into one of two categories:

- Vacuum handling applications
- Gripper handling applications

SELECTING THE CORRECT METHOD

The actual part or product to be handled will help determine the correct method. Parts with large, relatively smooth surface areas generally fall into the vacuum handling category: sheet metal, wood, glass, plastics, cardboard, plate steel, and paper—parts ranging in size from an automobile roof to a pack of cigarettes. Parts without large, smooth areas lend themselves to handling with one or more mechanical grippers with fingers designed and contoured to fit the part configuration: rounds, squares, cylinders, and rectangles—items such as shafts, splines, hubs, and gears.

VACUUM APPLICATIONS

If a vacuum is called for, it is a good idea to have a basic working knowledge of the principles of vacuum technology and the commercial products available. Vacuum cups are manufactured in a variety of shapes and sizes. The most common are the round cups that range in size from 1–5 in. diameter and the oval cups 2–8 in. diameter. Most are available in a durometer range of 30 to 60, and are molded in either neoprene or urethene compound. The best choice is a cup that is molded over a metal supporting insert for strength, and that offers a reinforced lip to resist cutting or tearing. Cups flex and distort and must return to their original shapes with every cycle, so a cup with good memory qualities is essential.

Venturis. One of the most commonly used generators of vacuum is the venturi. All venturis, regardless of their size or shape, function in the same manner—no moving parts. They are based on Bernoulli's principle that an increase in velocity creates a decrease in pressure. Venturis accept standard shop air regulated down to an efficient 22–32 psi. Air flowing through a larger orifice creates a vacuum through the smaller cross-orifice where the vacuum cup is attached. Air consumption is typically 5–9 cubic fpm. A properly adjusted cup will hold 10 lbs/in.^{2} of cup area and each cup can hold 10–100 lbs with a 2:1 safety factor.

Multiple cups are each fitted with their own venturis, ensuring faster venturi evacuation time and preventing the part from being dropped if the cup is damaged or the air line severed. There are two styles of venturis used with vacuum cups—fixed (nonadjustable) and adjustable:

- Fixed. The block type venturi has a piped tap for attaching the cups. It is assembled by means of a close nipple.
- Adjustable. Such a system may be

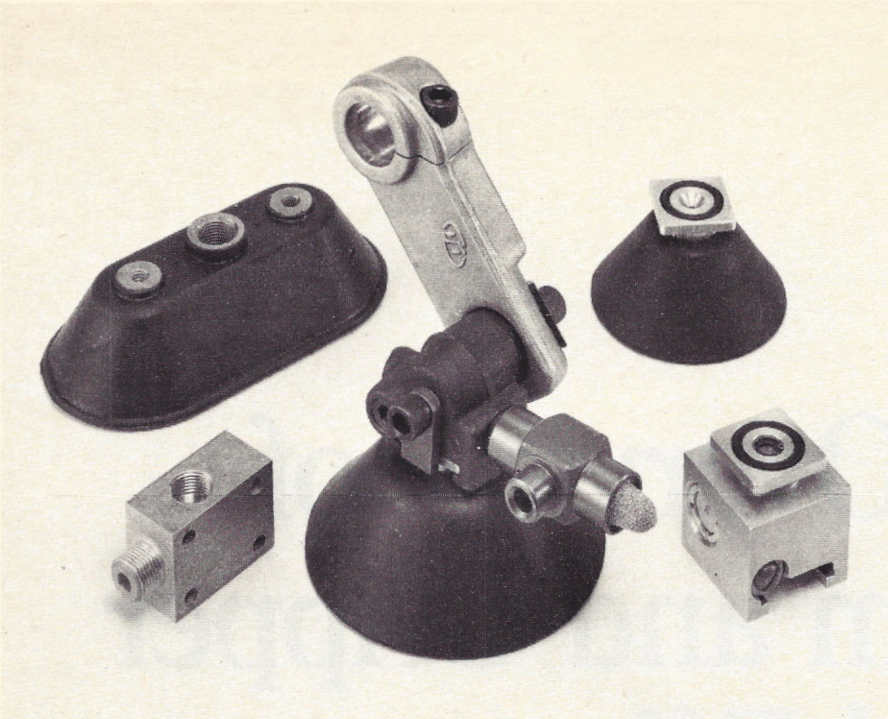

Photo 1. The Vaclok™ vacuum gripper assembly consists of the venturi (left front), the vacuum actuating valve (right front), and a vacuum cup. Cups can be oval (left rear) or round (right rear). The completed assembly is shown center on its mounting bracket.

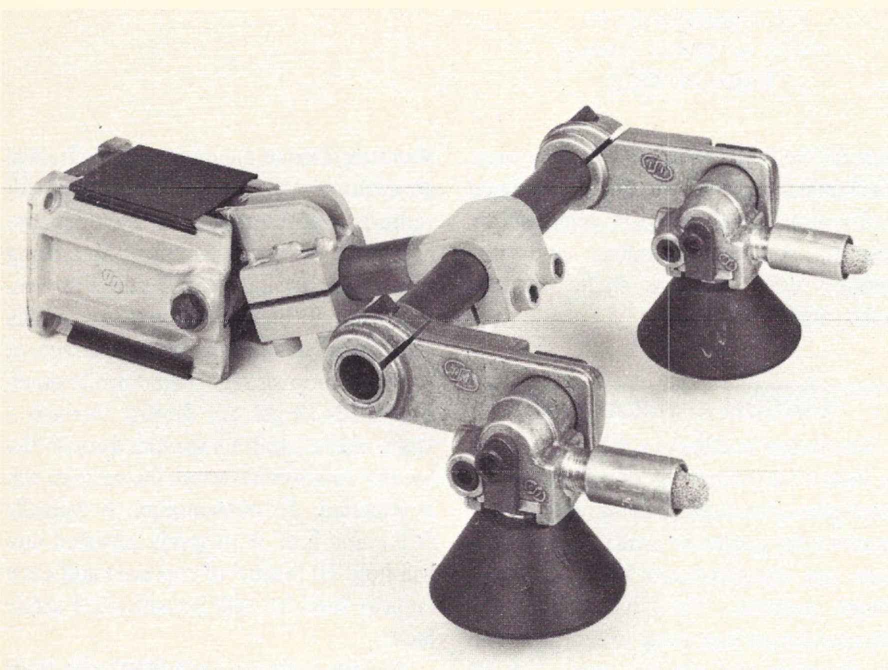

Photo 2. Multiple vacuum cups can be used when the payload is heavy or difficult to balance.

desirable when a variety of shapes and sizes is to be handled. Adjustable venturis, such as the Vaclok™ vacuum cup and venturi assembly combination offer a T-slot attaching cup and venturi that quickly detaches for replacement without disturbing the angular positioning of the mount and bracket arm (Photo 1).

The Vaclok system is available with an adjustable bracket arm that offers 360 degrees orbital and 30 degrees angular positioning. Most venturis and bracketry should be of aluminum, light but of rigid construction in order to minimize end-of-arm weight.

Some popular and useful options available on vacuum end effectors are:

- The vacuum actuator valve is a dual purpose device that fits between the cup and the venturi. It offers part blow-off, a quick release that upsets the vacuum seal and seals in and maintains vacuum should the vacuum air supply line be accidentally severed or interrupted.
- Vacuum head options offer auxiliary lift to lower or raise the cups vertically or angularly. The gripper used for this action has its links removed. A variety of bases is available.

Sizing the System. The considerations are overall size of the part, surface irregularities (smoothness, porousness of material, sharp breaks), weight of part, and multiple cup placement for balancing the load (Photo 2). Vacuum sensing devices currently available include pressure switches and external proximity or limit switches that indicate the presence of the part throughout the handling cycle. These devices can be mounted to the vacuum tooling or bracketry.

MECHANICAL GRIPPER HEAD HANDLING APPLICATIONS

When selecting the proper end-of-arm tooling devices, the part to be handled must be evaluated according to the criteria of weight, overall size, length, balance points, and class of the part. The part weight and size should be allowed to determine how many and what size heads to use. Commercially available gripper heads are generally found in three sizes: mini, 4 lbs; standard, 7 lbs; and heavy duty, 12 lbs. These heads are manufactured with 10 standard gripping finger configurations, each made to grip vertical or horizontal flanges. The part requirements should determine the fingers' configurations (Photo 3).

Since the gripper will be loading or unloading the parts directly to and from the fixture, the fingers will necessarily be entering the fixture's tooling area and must not interfere with existing gauges, cutters, and other portions of the fixture. Although it is recommended not to compromise the strength or position of the gripper fingers' placement on the part, sometimes altera-

tions to the fingers and their positions must be made to clear existing fixturing or tooling.

Basics of the Most Commonly Used Standard Gripper Heads. The body is of two-piece machine tool construction. The links and pins are hardened and ground. A T-slotted piston rod attachment allows rapid changeover and removal. The gripper body is mounted to the base by four socket head cap screws on square centers. Swivel attachments are available to mount and adjust the head to any angle from 0 to 360 degrees. The upper and lower fingers move in unison 21½ degrees for a total opening of 43 degrees when actuated by a 1⅜ stroke cylinder. One of the two moving fingers can be locked out or immobilized by removing the links that control that movement. The degree of finger control can be reduced or limited by restricting the cylinder stroke. The cam operated gripper heads offer a parallel finger movement of 1–2 in., and each finger moves in unison and parallel to the other. The cam operated movement head is desirable when a variety of part sizes is to be gripped.

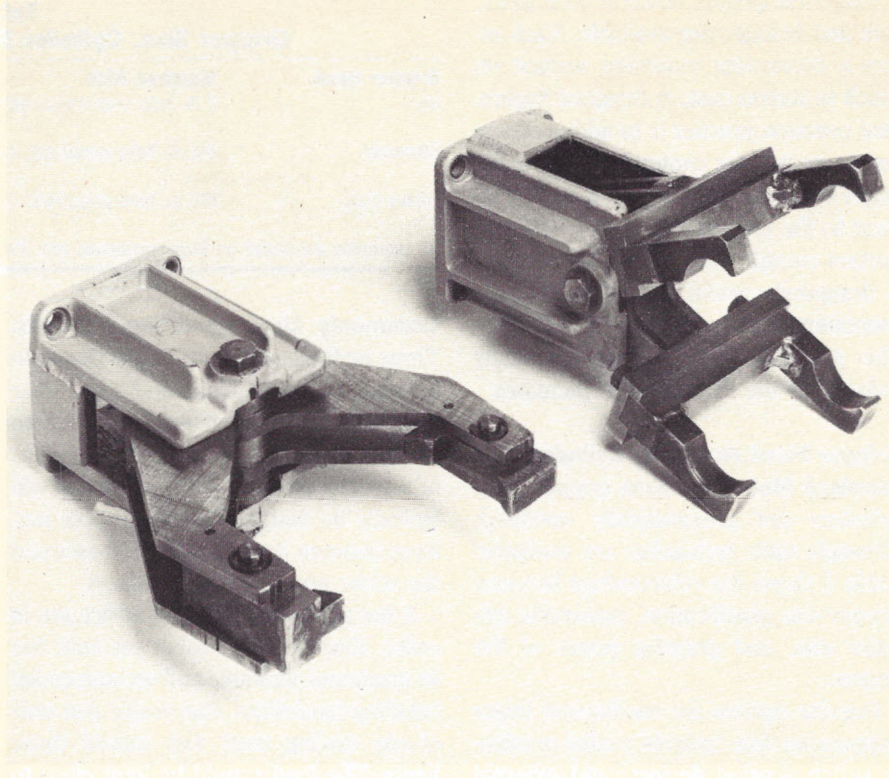

Photo 3. Custom gripper fingers can be mounted on standard gripper heads. The fingers on the left are suitable for wide cylindrical shapes while those on the right are designed to grip long, thin objects such as rods, and have dual contact points for stability.

Fingerless gripper heads in both styles, cam and linkage, are available. Each offers a convenient mounting surface on which to station custom designed fingers. One common practice is to add urethane inserts, sometimes contoured to the exact shape of the part; these inserts can be affixed to the ends of the fingers. One important consideration when the customer is designing custom fingers is to avoid overextending the length of the fingers. The gripping force is proportionately reduced as the finger length increases.

Gripper Head Actuating Cylinders and Standard Mounting. Most gripper head cylinders are pneumatically operated, although some hydraulics are available. Table 1 shows the relationships between gripper size specification, pneumatic cylinder size, and gripping power of the fingers.

Popular options for mechanical finger grippers are flow controls, ported proximity switch sensing devices, and external limit switch mounting, all of which signal that the part is present and the fingers are closed.

Table 1
Gripper Size, Cylinder Size, and Finger Pressure

Gripper Head	Matched With	At 80 lbs PSI
Mini	2 in. bore pneumatic cylinder	Fingers extended to 2½ in. Develops 502 lbs of finger pressure
Standard	2½ in. bore pneumatic cylinder	Fingers extended to 3½ in. Develops 504 lbs of finger pressure
Heavy Duty	3¼ in. bore pneumatic cylinder	Fingers extended to 4½ in. Develops 568 lbs of finger pressure

All examples are based on finger pressures with the fingers fully closed.

Commonly Used Mounting Methods. Three methods of mounting are frequently used: Angle L (front and rear), rear flange mount, and front flange mount. Two or more heads can be mounted by means of a special bracket. An adapter pad will typically be designed to match hole patterns between the gripper head bases and the robot arm mounting surfaces.

A few additional words of advice are in order. Even the best robot yet built has its maximum allowable and recommended handling capabilities. Part weight plus end-of-arm tooling must not exceed those limits. The load should be kept close to the end of the robot's arm—overextending the tooling creates a potentially untenable cantilever. Mounts and cylinders should be built with high strength aluminum alloys when possible.

A standard, commercially available gripper head, mount base, and cylinder system can today be purchased for under $500. The vacuum system is generally under $300. A careful selection of custom add-ons can make a generic robot the right one for the job.

Ron Micallef is Product Sales Manager for I.S.I. Manufacturing, Inc.

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To rate this article, circle the appropriate number on the Reader Service card.

1	11	21
Excellent	Good	Fair

Applications and Procurement of Automatic Guided Vehicle Systems

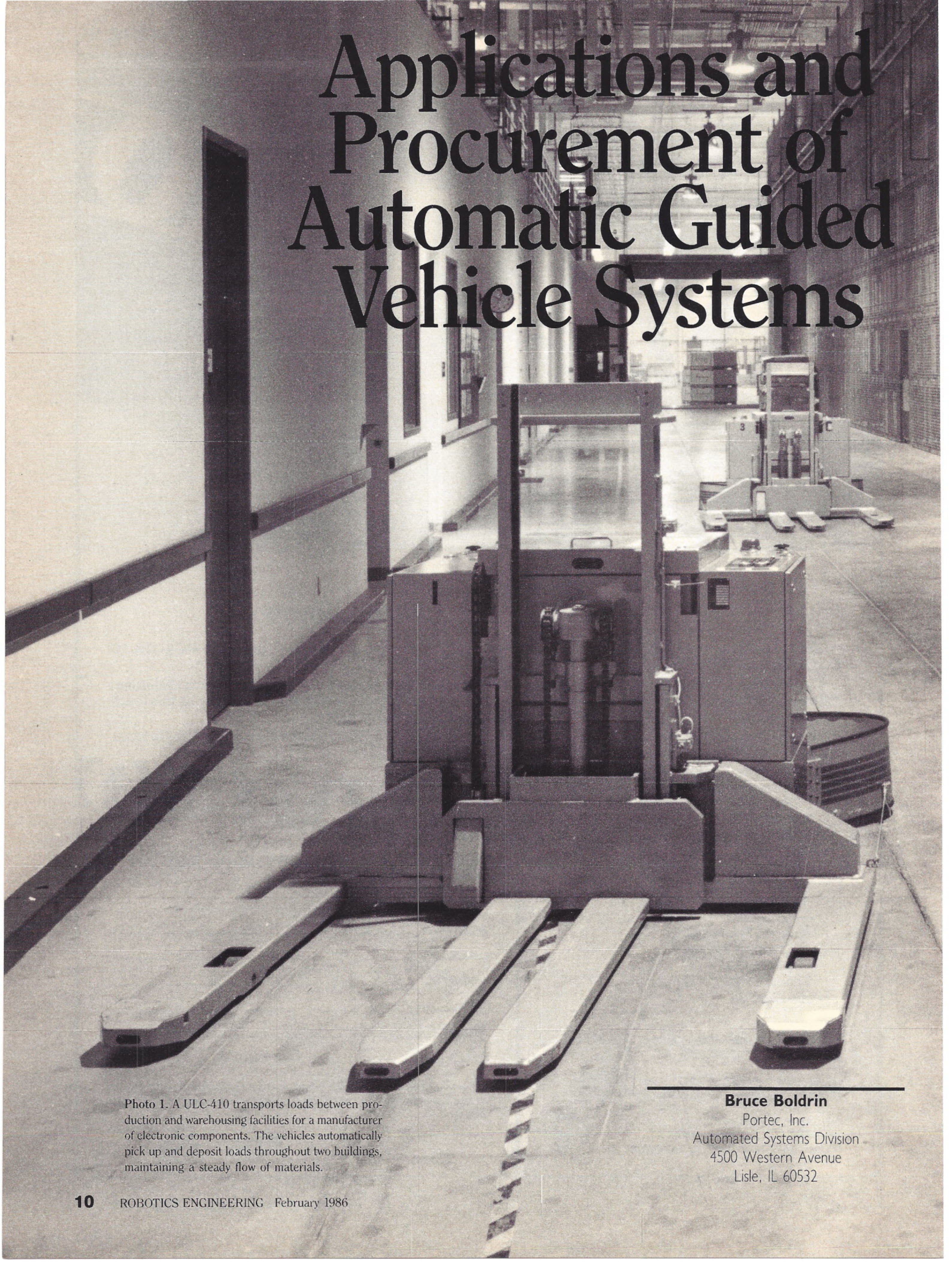

Photo 1. A ULC-410 transports loads between production and warehousing facilities for a manufacturer of electronic components. The vehicles automatically pick up and deposit loads throughout two buildings, maintaining a steady flow of materials.

Bruce Boldrin
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Automatic guided vehicle systems (AGVSs) are used in manufacturing, assembly, and distribution (stockroom) applications. They can be standalone or an integral part of another system. Originally designed for horizontal transportation of palletized material, the current variety of vehicle models and controls parallels that of industrial robots. Improved methods of load movement are complemented with computer tracking of material. At the sophisticated end, an AGVS closes the traditionally open loop of material tracking on the shop floor. At the unsophisticated end, an AGVS replaces traditionally labor intensive fork truck or manual movement of material.

Almost all AGVS share four characteristics: they are driverless, battery powered, automatically guided, and automatically positioned. Beyond these features, there are substantial variations in the forms, functions, and controls of automatic guided vehicles. The main descriptor of an AGVS is the vehicle style, and secondarily the control system. Other attributes include the type of guidance employed and the load adaptor. Since many guided vehicles were derived from industrial trucks by adding sensors and controls, AGVS classifications include similar vehicle names:

- Driverless tractor: Primarily used for towing trailers. Automatic and manual loading. Optical and wire guidance.
- Low lift transporter: Based on the Walkie class of industrial trucks. Moves loads from one floor position to another. Automatic and manual loading.
- Unit load transporter: A broad classification of vehicles that includes pallet and tote pan transporters and assembly platforms. Typically wire guided and designed for heavy industrial use. Often employs direct computer control, with on-line communication to the shop floor control system. Automatically picks up and deposits loads.
- Forked vehicle: Includes straddle and counterbalanced vehicles. Automatically picks up and deposits loads at floor and elevated heights (including pallet rack). Typically under computer control. Capable of stockroom applications, but normally used for work in process (WIP) storage.
- Narrow aisle storage vehicle: Used for vertical storage of WIP and stockroom material. Handles unit loads, including pallets, skids, and pans. Transfers loads with shuttle and turret load handlers. Typically applied as a subsystem within an integrated flexible manufacturing or production facility. Under computer control.

A SYSTEMS PRODUCT

An AGVS is a systems product. This poses special considerations for the purchasing manager and project team. The vehicles can be embedded within a process and they can travel throughout the facility. Consequently, they cross many department boundaries and areas of functional responsibility. When the control system is in direct communication with other computers, corporate management information systems personnel become involved. For an AGVS within manufacturing or assembly systems, the product may be designed for automatic handling, which involves design and manufacturing engineers. In summary, the evaluation and installation of an AGVS requires the participation of a team, including core and supporting members.

The core members of an AGVS project team include representatives from facilities, process engineering, and data processing/controls. Other supporting players are used when their areas of expertise are required. Since all AGVSs require capital expenditures, the team should have a management champion to assure resolution of departmental conflict and provide proper attention during evaluation and implementation.

This approach is recommended to avoid some of the pitfalls encountered by companies that take a short cut approach in lieu of effective planning. Two of the less successful approaches have been "jumping in" and buying a "test cell." Jumping in has often meant overlooking the need for an AGVS to fit corporate long term goals and controls architecture. Some significant load categories might be arbitrarily excluded from the system in the interest of expediency. Further, the chances of a significant group within the corporation being overlooked, personnel who will have eventual responsibility for or control over the system, is highly probable. Test cells have been succesful when included as part of a total plan and used to educate and develop processes critical to the end system. Too often, however, test cells are a substitute for thorough consideration of what is best for the entire corporation. An effective evaluation and purchase of an AGVS will help to avoid these and other pitfalls.

KEY STEPS OF SUCCESSFUL AGVS IMPLEMENTATION

Several companies deeply involved in the implementation of computer controlled, integrated systems have developed a set of rules to guide the project team. Hewlett-Packard and General Electric are two leaders in computer integrated manufacturing (CIM). Their steps for implementing CIM systems are similar in thrust, and directly applicable to AGVSs. In paraphrased form, they are as follows:

Learn AGVS Technology. There are currently more than 30 AGVS vendors in the U.S., up from half a dozen in 1979. There are hundreds of systems and thousands of vehicles to be seen. The press for material handling, manufacturing, and automated systems is full of survey and application articles. There are regional and national seminars on AGVSs. The 1984 *Materials Handling Handbook*, published by John Wiley and Sons, has an extensive chapter on AGVSs. Through a program of study, presentations by AGVS vendors, and site visits, your project team can develop a practical comprehension of AGVS technology.

Set Goals. In this step, it is important that the goals of an AGVS are consistent and supportive of corporate strategies. For example, if the corporate strategy is to minimize inventory, one of the techniques available is Just In Time material delivery. The AGVS complement of this strategy could be direct delivery of material from the receiving dock to the point of use.

Choose the Right Team. Successful implementation will require the best players. They should be creative, since they could modify the way your company does business. To properly develop the required information, and an understanding of the workers' attitudes toward this form of automation, team members should have interpersonal skills. What they learn will be very important in setting the climate for acceptance and effective use of the system.

Look Hard at Your Current Operation. The data required to evaluate an AGVS is the same information needed to evaluate your current operation: material movement paths and rates, container sizes, labor intensity and use, degree of control (material tracking), and environmental conditions. This data should be analyzed and the best manual alternatives evaluated before an AGVS or other automation should be considered. Two main benefits will be realized:

- Intrinsic problems might be corrected, with commensurate productivity improvements, at a very attractive payback.
- A solid business case for comparison of the AGVS will be established.

Prepare a Broad Justification. AGVSs affect more than direct labor. With the ability to track material, an AGVS can save indirect labor and inventory, and thus reduce storeroom space. Replacing boring tasks that require precise load positioning and eliminating dangerous work have been the basis for justification for both robotic and AGV systems. Working on AGV supported assemblies at rest produces a higher quality product than working on moving assemblies. Additionally, the assembler can perform his or her own inspection and release error free work, practically eliminating formal inspection. (See Table 1 on justification criteria.)

Plan from the Top Down; Implement from the Bottom. From the corporate goals, and the subsequent analysis by the project team, a master plan should be developed. Steps in the plan, such as a phased installation or a prototype system to work out processes, are then important details leading to the end goals.

Allow Sufficient Time. Don't be stampeded into making short term decisions. On the other hand, don't delay decisions until the return on your investment is a moot point. The ability to deliver an AGVS is a function of industry capacity. Current project schedules of 10 to 14 months after receipt of order are typical. These schedules are based on the project tasks to define, design, manufacture, program, install, commission, and train user personnel.

Select Your System Supplier with Care. Choose suppliers with a proven track record, those who will stay with you in the long run. Investigate their customer base, and look for systems comparable to what you are considering purchasing. Do the vendors have the internal organization to design, install, and properly support the system after acceptance? What is their

documentation? Training? Parts and service programs? Does your project team have a good rapport with the supplier?

Success Depends Upon Acceptance by Personnel. A planned program of informing plant personnel as the project goes through phases of installation has proven effective in gaining initial acceptance and ensuring a continuing favorable attitude toward the system.

METHODS OF AGVS PROCUREMENT

Competitive bid is the most common method, with quotation to the owner or a general contractor. The following is a summary of the types of contracts in general use.

Competitive Bid to Owner. This enables the project team to maintain close contact with the supplier's solutions and provide good technical and financial evaluation.

Photo 2. A ULC-335 engine dress vehicle automatically adjusts the platform height for the task, resulting in less worker fatigue, improved quality, and increased productivity.

Circle 36

Circle 45

Table 1
Justification Criteria

Criteria	Material Handling System	Flexible Assembly System	Flexible Manufacturing System	Narrow Aisle
Direct Labor Savings	•	•	•	•
Indirect Labor Savings	•	•		•
Space Savings				•
WIP Storage Reduction	•		•	•
Just In Time Production	•	•		
Paperless Control	•	•	•	•
Improved Product Quality		•	•	
Expanded Job Scope		•		
Replace Dull, Precise Tasks	•		•	
Replace Hazardous Tasks	•		•	
Low-Cost System Relocation	•	•		
Expand To Meet Production	•	•	•	•

AGVS suppliers usually provide complete (but not turnkey) systems. Therefore, the relationship between team and supplier is important to the ultimate success of the system.

Competitive Bid to General Contractor or Automation Integrator. This method is typically used in new plant construction or modernization of existing facilities. It relieves the owner of some legwork and direct responsibility—at a fee. In order to protect his interests, however, the owner remains involved. The resultant three-way relationship can slow decision making and disrupt the proposed schedule. Major AGVS suppliers have competent project management departments to ensure that decisions are made and schedules met.

Phased, Negotiated Contract. The owner's team determines which supplier has the best product and services. The owner then contracts for a feasibility study, which results in a selection of the best alternative with close budgetary pricing and preliminary schedules. A second contract follows, commissioning the supplier to design the system and to develop a firm price and schedule. While the second phase is in progress, the owner secures an appropriation to be used to begin the phase 3 implementation contract as soon as phase 2 is completed. Safeguards for this fast track approach include clauses that the final system design will meet the justification criteria and that the design will be approved.

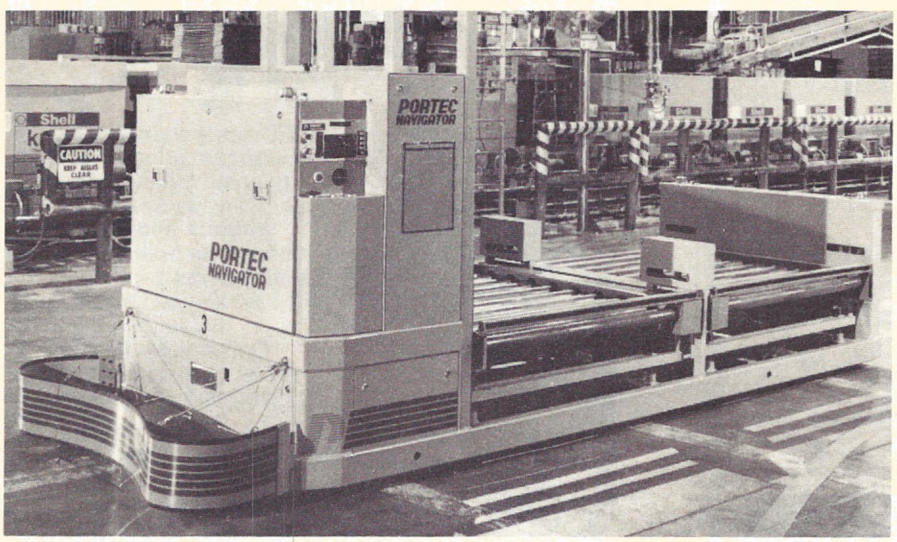

Photo 3. Navigator control flexibility allows material consumption and delivery rates to be more evenly matched through linkage to information management systems. Vehicles like the ULC-370 become part of overall inventory management.

Sole Source. After the evaluation phase, the project team may find an AGVS, or vendor, or both that provides unique and valuable solutions to the owner. In this case, a sole source procurement is recommended. "Open book" pricing should be used, with a joint review of subcontractor bids to make sure the owner receives proper value.

REQUEST FOR QUOTE ESSENTIALS

Overlooking essential elements in the request for quote process has caused misunderstandings, unnecessary reiterations, and lost time. Points to remember are:

- Prepare a statement of system function and performance.
- Describe the operating environment.
- Set the time frame.
- Define specific responsibilities.
- Set forth the terms of payment.
- Hold an acceptance test.
- Set safety standards. Until standards specific to AGV systems are established, use general OSHA safety standards.
- Establish contractual conditions with considerations specific to length of warranty (in months and shifts) and ownership of software.

CONCLUSIONS

Automatic guided vehicle systems are a tool of major importance in improving and integrating the flow of material in manufacturing, assembly, and distribution operations. These improvements are the result of better methods of moving and tracking materials. Justifiying their purchase includes productivity improvements and other significant factors. Recognition of an AGVS as a systems product is a critical factor in allocating resources for planning, evaluation, and procurement.

Bruce Boldrin is Navigator Marketing Manager for Portec Automated Systems Division.

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A Decision And Cost Effectiveness Study of Robotic Grippers

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Worthington, OH 43085

To pick up and move an object of a specific shape, a simple hand with one degree of freedom can be designed. This gripper approaches the object and moves its fingers in one dimension to take hold of the part. In many robot applications this design is entirely adequate. However, when a manufacturing operation changes the shape of the object so much that the original hand can no longer grasp the object, it becomes necesssary for the robot to use an advanced gripper. This is also true when several objects of different shapes are handled, as in assembly.

To take full advantage of a robot's versatility, an equally versatile hand system must be available. Four methods are generally recognized for the manufacturing engineer's use in improving robot hand versatility. First, the fingers can be mechanically interchanged during the cycle. Second, the entire hand can be interchanged. Third, a combination gripper (the so-called "flip-over" hand) can be used. Finally, a multiple prehension hand can be used. There are many robot hands today that fit into these categories.

Each of these systems has advantages, and the manufacturing engineer should consider the complete spectrum when making a decision on a robot gripper.

AN ANALYSIS OF GRIPPING METHODS

Most robots have an end effector that is called tooling because it is designed to do a specific task. Manufacturers of industrial robots have conceded that the versatility of their machines is limited to the versatility of the end effector. To improve the versatility of the robot, some companies have worked toward the development of more versatile gripping devices.

> RULE 1
> **A production machine should never be sitting idle waiting for a robot to complete a tool change or material handling cycle.**

Changing Fingers. To broaden the capabilities of the simple gripping hand, some manufacturers developed a hand that changes fingers. To do so, the robot moves its hand to a station away from the work zone, where it releases its current set of fingers into a holding device. It then moves to another set of fingers, locks them into the hand, and withdraws the hand from the holding device. The hand with the new fingers then returns to the working area.

If the manufacturing engineer is fortunate, the process of changing fingers occurs when the robot arm is idle (as in waiting for the machine it is tending). However, in many cases, a machine with a finished part would be waiting for the robot to change fingers and return to move the part. If this took only three seconds out of a 30-second machining cycle, the loss in productivity would be a disastrous 10 percent.

Changing Hands. Some companies have designed a mechanism to change the entire robot hand. The hand is separated from the robot wrist and a new hand is inserted, a process that can be completed within a few seconds. When the entire hand is interchanged, new fingers and a new finger bending mechanism is made available to the robot.

This concept has advantages over changing fingers because it allows the robotic system to handle objects of significantly different shapes, or to change tooling and to perform a manufacturing function other than material handling. But changing hands, like changing fingers, requires the robot to interrupt a productive cycle so that it can remove one hand and acquire another.

Changing hands can require very nearly the same amount of time as changing fingers since the arm must move to a new location, deposit the hand, move to the new hand, pick it up, and then return to the work station. If the production machine is waiting while the robot acquires a new gripping device, valuable cycle time is lost.

Flip-Over Hands. To avoid cycle time lost while the robot is changing hands or fingers, some manufacturers have designed "flip-over" hands. With this multiple hand system, the robot has several gripping devices attached to its wrist at the same time. By rotating its wrist, or through some other independent motion, the robot can move a new hand to a desired position for use at the work station. Very little, if any, cycle time is lost with this concept.

The primary disadvantage of a multiple hand system is that the robot carries each hand all the time. This increases the mass at the end of the robot arm, the most detrimental point considering robot dynamics and payload capability. Most robot manufacturers specify their robots' payload capacity as a combination of "tooling plus workpiece." Replacing a 10-lb. robot hand with a 20-lb. robot hand, all else being equal, decreases acceleration and deceleration. Repeatability can also degenerate, depending on the robot design, and the maximum work piece weight is reduced.

RULE 2
Always keep the mass at the end of the robot arm at a minimum value.

Multiple hands and the control mechanism can be very expensive. In a complex operation (like assembly) the robot could require many hands to complete a task.

Multiple Prehension Hands. A multiple prehension hand can change its gripping pattern by simply changing the finger bending directions. The most important advantage of a multiple prehension hand is its ability to instantly adjust and grip randomly shaped parts. Prehension changes are made as the arm moves toward the next part. There is no situation in which the production machine will be sitting idle, waiting for the robot to acquire a gripping device.

A multiple prehension hand can be quite economical compared to special tooling. Multiple prehension hands, because of their versatility, are sold in larger quantities. The expenses for design and engineering are written off over these larger quantities, making the grippers extremely cost effective. They can perform the tasks done by custom designed tooling, quick-change hands, quick-change fingers, and flip-over hand mechanisms.

THE VERSAGRIP III MECHANICAL HAND

The Versagrip III mechanical hand is a multiple prehension hand designed to improve the productivity of industrial robots by reducing the cycle time necessary for tool changing and increasing the payload capabilities of the robot by eliminating combination gripping devices. The hand uses only two motors: the first bends all three fingers simultaneously and the second rotates two of the three fingers to change the prehensile patterns. Only two I/O devices are needed to control the hand.

Over-constraint is avoided by designing rigid fingers. These fingers do not curl, but simply bend about revolute joints at their base. Photos 1 and 2 show the hand in a wrap prehensile mode. Photos 3 and 4 show the hand in 3-jaw prehension.

Electric stepping motors are generally used to rotate the fingers between the various prehensile modes. The motors can be programmed to stop at an intermediate point during finger rotation to match the pattern for almost any irregularly shaped

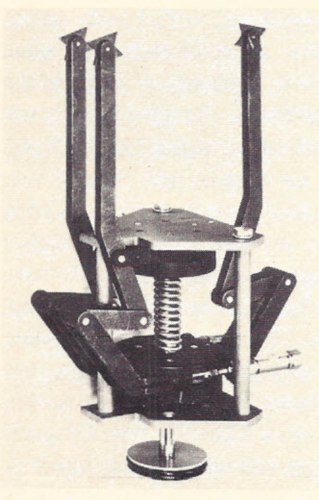

Photo 1. The Versagrip III hand is shown in an open configuration of the wrap prehensile mode.

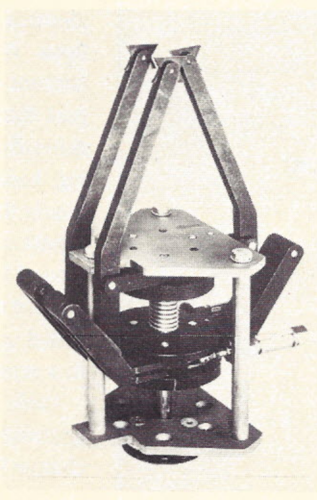

Photo 2. The hand is shown flexed in the wrap prehensile mode.

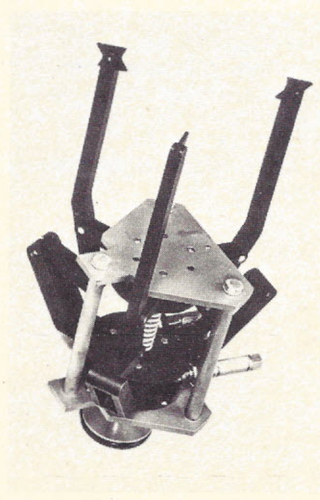

Photo 3. The Versagrip III hand is shown open in the 3-jaw prehension mode.

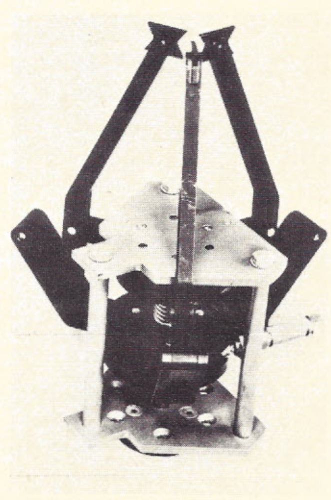

Photo 4. The hand is closed in the 3-jaw prehension mode.

object or surface. Air cylinders are recommended to open and close the fingers. They can generate moderate forces, have a high no-load velocity, and are lightweight in construction.

GRIPPING MECHANICS

Often the manufacturing engineer can influence the shape of the object the robot will grip by working with product engineering to specify a "surface configuration." Surface configurations are areas on the true surface of the part where an artificial shape has been established for the robot fingers to contact. Surface configurations can be added in many ways; for example, material can be removed from the part or added to it, forming extending surfaces. A mechanical hand, when gripping an object with large, flat, parallel surfaces, will have difficulty establishing a positioning accuracy. The hand can grip and hold the object in many places along the surfaces. Cylindrical and spherical objects, on the other hand, tend to nest within the fingers, establishing an improved repeatability for both the gripper and the robot.

RULE 3
Whenever possible, an object should be gripped on a cylindrical or spherical surface. The gripper should have 3-jaw prehension capabilities.

The manufacturing engineer also has a great amount of control over the robot's program. By making changes in the program he can cause the end effector to grip an object in the most desirable location. However, at this stage, the statics and dynamics of the work piece in motion as well as the shape of the object to be gripped must be taken into consideration. For example, a 2-foot long work piece may have a cylindrical "handle" at one end that is well suited for the robot to grip. But picking up the work piece at this point significantly increases the moment of inertia and torque at the gripper. The best place to grip this work piece would be near the center.

ECONOMICS DURING AUTOMATIC ASSEMBLY

Assembly is an excellent area in which to study the cost effectiveness of the various types of robot grippers. Robotic assembly is typically done with a single robot selecting parts from several feeders and stacking them on a base. The base or frame is presented and the completed assembly is carried away by a shuttle system. This study is of a water mixing valve on a clothes washing machine. The parts are listed in Table 1.

Table 1
Parts for Water Valve

Sequence	Parts Name	Quantity Used
1	Coils	2
2	Brass Retaining Cups	2
3	Springs	2
4	Armatures	2
5	Diaphragms	2
6	Body	1
7	Metal Frame (added by the shuttle system)	1

Justification for automation in this example would be the reduction in labor man-hours. The assembly robot would generally have to be capable of adding one part every 4 seconds, making total assembly cycle time 44 seconds. This rate is approximately equivalent to two workers on three shifts, or $150,000 annually. Considering robot maintenance, loading parts, and miscellaneous operation man-hours, the annual payback is $112,500.

Quick-Change Fingers and Hands. Changing fingers and hands are nearly identical operations, in that both operations require approximately the same amount of time. A change of shape in the part that motivates changing fingers will generally motivate changing hands. Changing hands (or fingers) will require very nearly the same amount of time as adding a part since the arm must rotate and/or extend to approach the changing fixture, deposit the hand, move to the new hand, pick it up, and then move to a parts feeder. In a sense, adding a hand is adding a part.

Table 2 shows the cycle time for various gripping devices. The cycle time for quick-change fingers and quick-change hands increases to 56 seconds because 11 parts plus three changes is the equivalent of 14 independent arm motions.

"Nesting" of assemblies may be possible in order to minimize the number of quick changes. This practice is quite common in electronics. Nesting will spread the amount of cycle time dedicated to quick changes over a greater number of assemblies, resulting in greater productivity. Sometimes, however, the mechanical requirements at the work station restrict the use of nesting.

Table 2
Cycle Time for Various Gripping Devices

Gripper Type	Number of Parts Added	Quick Changes	Total	Cycle Time
Quick-Change Fingers	11	3	14	56 seconds
Quick-Change Hands	11	3	14	56 seconds
"Flip-Over" Hands	11	0	11	44 seconds
Multiple Prehension Hands	11	0	11	44 seconds

RULE 4

Whenever quick-change fingers or hands are used on an assembly robot, parts should be nested to the extent that the work station allows. Building too large a nest, however, will decrease the robot's access to parts. Be certain to conduct an appropriate analysis for diminishing returns.

Table 3 is an analysis of cost effectiveness for robots with various gripping devices.

Table 3
Cost Effectiveness of Robots with Various Gripping Devices

Gripper Type	Robot System Cost	Tooling Cost	Payback	ROI
Quick-Change Fingers	$100,000	$9,000	1.8 years	56%
Quick-Change Hands	$100,000	$20,000	1.9 years	52%
"Flip-Over" Hands	$100,000	$27,000	1.6 years	64%
Multiple Prehension Hands	$100,000	$13,000	$1.4 years	69%

Multiple Prehension Hands. Many studies have been done to compare the cost effectiveness of the multiple prehension hand with other options. Whenever the shape of the parts that the robot must grasp changes, the multiple prehension hand has shown itself to be the most cost-effective alternative.

Frank R. Skinner is President of Robo-Tech Systems, Inc. His firm has recently received a NASA contract to pursue research on "Control Theory and End Effector Laws Using An Advanced Multiple Prehension Gripper."

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Changes Come Quickly To Quick-Change Tooling

Joseph Alvité
and
Chris Nimtz
Mecanotron Corporation
1728 North Second Street
Minneapolis, MN 55411

Advanced quick-change tooling systems actually pre-date the use of robots. The nuclear and hazardous materials industries, for example, created remotely controlled manipulators that could switch end effectors without exposing human operators to dangerous environments back in 1959. Obviously, these systems had to be both accurate and safe, and had to respond quickly to unforseen circumstances.

The first such systems, built by General Mills for its then nuclear power division, included a manipulator that could alternate between parallel grippers and a hook. In the 1960s, systems were developed with additional tools which the manipulator would plug in before using. These all-electric systems could weld, cut metal, grind, and perform other processes. Although the tooling was heavy and clumsy, it filled a vital need at the time.

With the development of the "modern robot" in the early 1970s, multipurpose turrets on which from one to six end effectors could be mounted were introduced. These rotational flanges performed several functions by presenting a different tool (end effector) to the work. Turrets are still used today, but suffer from severe limitations on the number of functions they can perform. Many times, the combined weight of the tools and the part exceeds the payload of the robot. Also, the tools mounted on the turret face are offset from

Photo 1. The URW's three-way locking mechanism gives a high degree of repeatability when exchanging tools.

the true centerline, thus posing programming challenges.

Quick-change tooling systems have made rapid advances in recent years. Along the way, these systems have become a major factor in the flexibility and cost effectiveness of automation. The financial advantages of quick-change systems (over manual exchange of end effectors) are straightforward: they allow robots to become more flexible and versatile, thereby increasing efficiency and reducing the need for additional capital investment. In addition, by reducing the down time required to change end-effectors to a minimum, the robot becomes more productive.

A few quick-change units employ axial feed-through systems with built-in pneumatic, hydraulic, coolant, electrical, and vacuum lines, eliminating exposed wires and hoses. As a result, robots that employ quick-change systems are less vulnerable to accidents, require less maintenance, and are generally cleaner and safer than those with manual tool changing.

Some of today's quick-change systems suffer from simplicity of design, though. They lack a self-cleaning capability; foreign substances may become lodged between the wrist and the end-effector, thus affecting performance. In addition, many lack adequate locking mechanisms to prevent the end effector from falling off the robot arm in the event of a power failure. This may seem like a small consideration, until one considers the added expense of damaged end effectors, parts, and the workpiece. A good locking mechanism also protects humans near the robot's work envelope.

Perhaps the greatest advantage that some current quick-change systems offer is the ability to verify, using vision and infrared sensing techniques, that the end effectors have been exchanged and the new process begun. Such sensors have been used to monitor part position and to control quality.

Mecanotron, a designer of end effectors and robot peripherials, provides three distinct quick-change systems for different functions. The URW offers a three-way

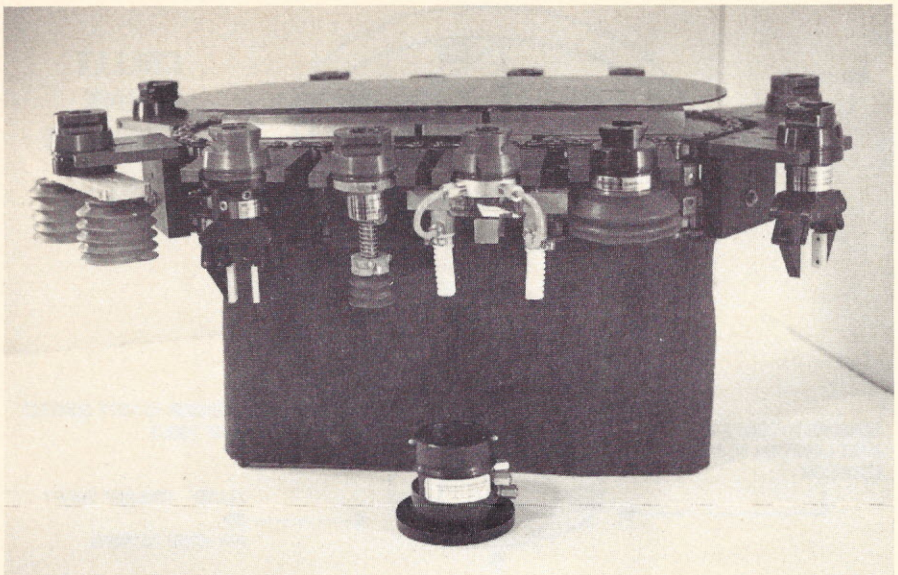

Photo 2. The computer controlled Feed System™ can hold up to 120 tools and provide them in any desired sequence. Placement outside the robotic workcell eliminates possible collision points.

locking mechanism that gives excellent repeatability when exchanging tools (Photo 1). The user has the options of pneumatic, fluid, and electrical connections. The URW can be used for exchanging pneumatic tools like parallel grippers, angular grippers, air cylinders, pneumatic drills, sanders, soft-finger grippers, vacuum end effectors, sensors, small motors, and electromagnets. These devices have been used by companies like GM and MTI to change grippers, motors, or torque nuts with a nut runner. The URW offers up to 15 pin connections on the smaller units. The maximum payload on the largest unit is up to 800 lbs.

The Flat-C (or Flat-Changer) is a unique device that opens like a regular vice; the fingers move perfectly parallel and centering pins lock tools in place. Possible electrical, fluid, and coaxial connections are extensive. Exchanges of fluid power are made without fluid leakage. Moreover, because of its construction this device has a high load-to-weight ratio, a minimal volume with the shortest mounting face, and payloads up to 3 tons.

Another Mecanotron quick-change system is the Collet Shank Changer, which allows a robot to use a variety of rotating tools (Figure 1). Deburring, for example, can be done with a deburring tool. A counter-sinking tool, a wire brush, or a sanding disk installed at the end of the shank can also be changed. Numerous applications include milling, drilling, countersinking, grinding, counter boring, and chamfering.

The collet changer is equipped with a proximity edge detector sensor that determines if the part is positioned within specified parameters. The changer has rotational capability that is provided by a built-in air motor with a full torque output over the entire speed range and is im-

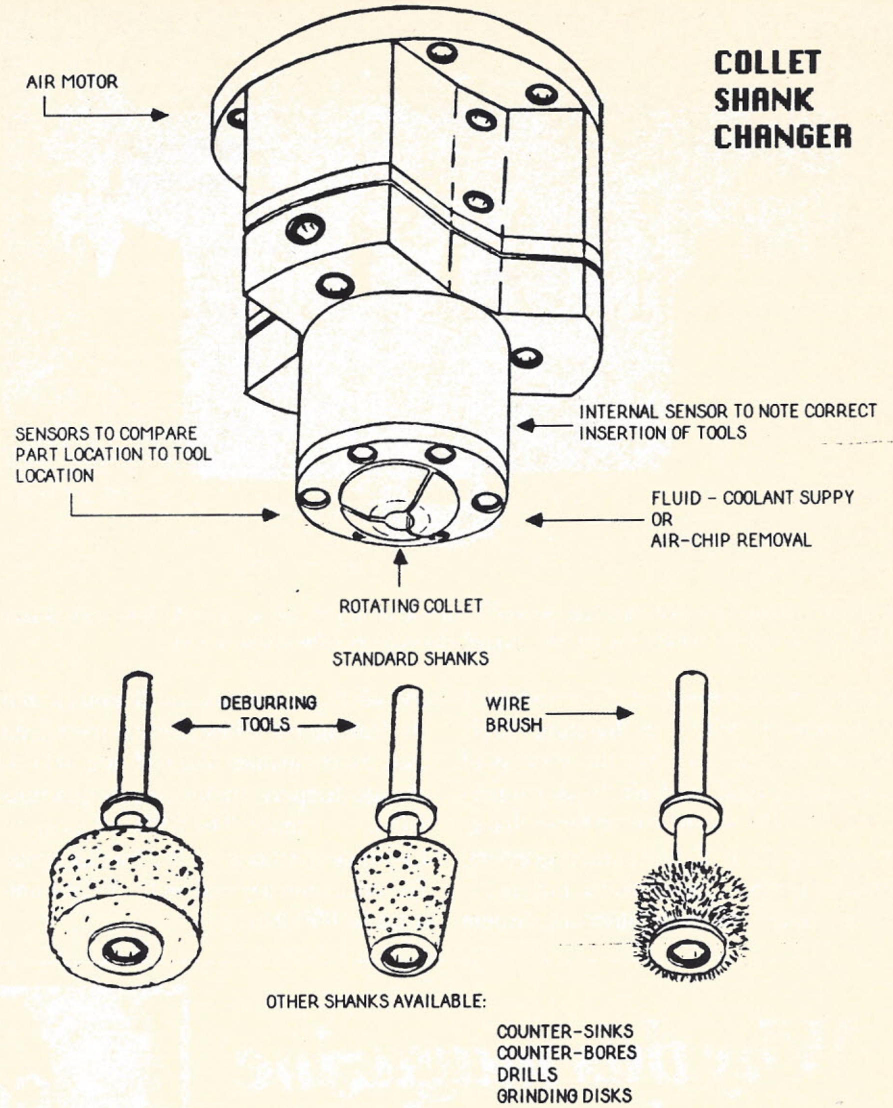

Figure 1. The Collet Shank Changer allows a robot to use a variety of rotating tools for applications including milling, drilling, countersinking, grinding, and chamfering.

mune to dirt, dust, moisture, and temperature. It is fairly quiet, explosion-proof, and easily serviced.

One of the greatest drawbacks of most robot systems is their reliance on operator assistance; humans are needed to monitor the system. Through the use of sensors and Mecanotron's end effector controller, the need for human supervision has almost been eliminated. The end effector and quick-change controller oversee the process and the equipment, while communicating remotely with a mainframe computer. This control system is a combination of hardware and software that allows the robot to process or move the part, monitor the process, and then keep track of the finished product.

Beyond their applicability to new quick tooling systems, these end effectors and quick-change tooling controller systems are an important factor in upgrading or retrofitting existing robots. This market will grow because of the rapid obsolescence of many robots; many have been or will be set aside because they were purchased for functions they could not perform. By using an end effector controller and the new quick changers, some of these robots can become productive again.

Joseph Alvité is Director of Robotic Applications and **Chris Nimtz** is a Research and Development Engineer at Mecanotron Corporation.

Reader Feedback

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4	14	24
Excellent	Good	Fair

Laser Guided Precision Positioning With A Gantry Robot

George Montalbano
and
Richard Schlais
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Project requirements sometimes require state-of-the-art solutions. The project here described called for the use of a robotic work cell for parts assembly and other processing operations. Two hurdles had to be overcome: the sheer overall size of the product—solid-fuel rocket motors, some as large as 8 ft in diameter and 40 ft long—was the first, and the second was to locate the rocket motor somewhere in three-dimensional space so the required family of parts could be accurately assembled to it.

The first hurdle was overcome by selecting a gantry robot with two work cells, 20 ft by 20 ft by 15 ft high, and 20 ft by 40 ft by 15 ft high. The dual mast configuration could reach and perform assembly operations over the entire length of the rocket motor.

The second hurdle proved more challenging. The following is a list of the various factors and problems that came into play.

1. Six different parts had to be assembled to the rocket motor.
2. The 5- to 10-in. parts had to be assembled to the motor with an accuracy of ±0.002 in. perpendicular to a datum line along the entire length of the motor. Enough gap and tolerance was allowed along the length of the motor to make longitudinal parts placement less critical (Figure 1).
3. A laser was used to provide a constant and precise datum line from which to base the movements of an X-Y indexer and the robot (Figure 2).
4. The motors were sling loaded in cradles and moved into position via rollers. The cradle was then clamped into position within the workcell (Figure 3).
5. Some motors required six parts to be assembled to the periphery and some required only three (three parts are shown in Figure 1). The length of the parts varied.
6. The accuracy of the robot within the workcell (from A to B) was ±0.017 in.
7. A quick-change feature had to be incorporated if multiple end effectors were to be required; the importance of this feature will become apparent later.

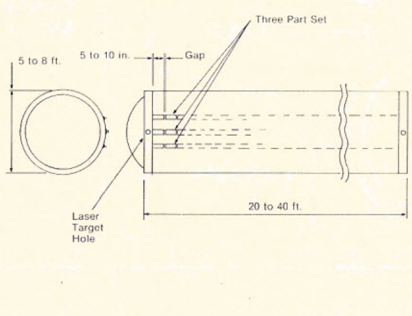

Figure 1. Parts ranging in length from 5 to 10 in. are mounted on a rocket motor. An accuracy of ± 0.002 in. perpendicular to a datum line along the motor's entire length is maintained.

After analyzing the second hurdle in light of the above factors it became clear that a number of techniques would have to be incorporated into the end effectors to accommodate all the possible contingencies. A typical sequence of events will illustrate the end effector requirements:

1. The operator goes through the initial startup operations.
2. The robot receives the necessary programming.
3. The robot is fitted with appropriate end-of-arm tooling. It was decided that two end effectors, one to place three parts and the other to place six, would be needed to satisfy the various configurations and patterns.
4. The robot moves into position, picks up the parts from a precision fixture,

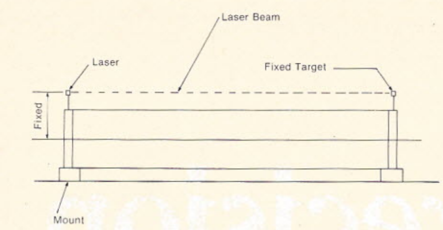

Figure 2. A laser provides a constant and precise datum line from which to base the movements of a precision X-Y indexer and the robot.

Two hurdles had to be overcome: the sheer size of the rocket motor and locating it somewhere in three-dimensional space.

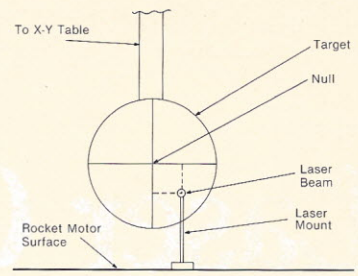

Figure 4. The X-Y nulling target is shown enlarged.

and locks them into its placement end effector.

5. The robot moves to a second position, where a bonding agent is applied to the base of the parts.
6. A laser (Figures 2 and 3) is activated and the robot is notified of the ready condition.

It must be kept in mind that the rocket motor is sling loaded in a cradle and roughly clamped in position. The laser, fixed mounted on the rocket motor, provides positional information to both the robot and the X-Y indexer so that they can work in conjunction over the entire length of the rocket motor. The laser target is mounted to the X-Y indexer. The laser and primary target are mounted on the rocket motor in very precise locations and the system is set. The robot then moves to the place where the parts will be bonded to the motor. In the process of moving to this point, the target mounted to the X-Y indexer breaks the initial beam. Once in position, the mast is locked and the secondary laser target on the X-Y indexer receives information from the X-Y coordinate system on the target. The indexer then moves the end effector until a null signal is received from the target. Only after the null signal is received does the end effector make the part placement (Figure 4).

7. The robot moves to its first assembly point and sets the end effector for further positioning and parts placement.

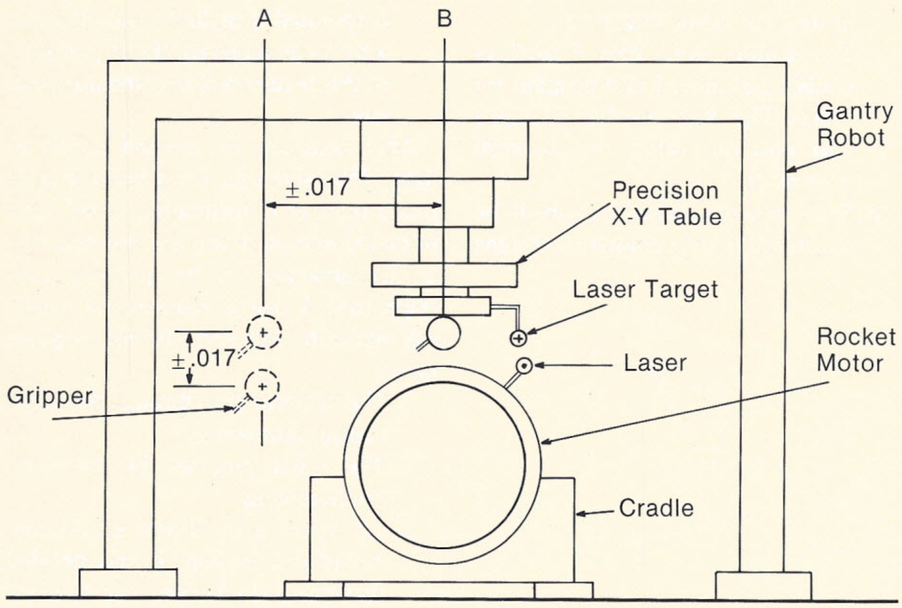

Figure 3. The motors are sling loaded in cradles on a gantry robot and moved into position via rollers. The cradle is then clamped into position within the workcell.

8. Braking mechanisms are then applied to the robot mast to maintain a given position throughout the remainder of the cycle.
9. Positional information is developed and transmitted from the laser and target system to a precision X-Y indexer built into the end effector and robot mast. The X-Y indexer then makes the fine adjustments necessary to place the part(s) on the motor. A compliance mechanism is incorporated into the end effector to adjust for any irregularities between the rocket motor, the part, and the bonding agent. Another compliance mechanism uses a 3-point contact to adjust for the non-critical longitudinal variations. The laser alignment head does not have the quick-change feature.
10. This position is held for a specified period of time to give the bonding agent time to set/cure. The parts are then unlocked and the robot retracts the end effector.
11. The robot then moves to the part position and the cycle is repeated.

It can easily be seen that special communications problems had to be overcome in order for the laser, the X-Y indexer, and the robot to work as a single system. The combination of software and hardware effectively closed the loop in the system without actually closing the loop. The workcell area and its surrounding environment are tightly controlled to prevent contamination of the laser and the information it supplies to the robot and X-Y indexer.

ADDITIONAL PROJECT REQUIREMENTS

The quick-change feature mentioned earlier has further implementation in this

project. Once the parts have been placed along the longitudinal axis of the motor, parts placement begins around the convex end of the motor.

Another style of end effector (Photo 1) picks up one of several differently shaped parts and moves to have a bonding agent applied to the part. The robot then moves to the placement position. Parts placement is required on only half of the surface of the convex end. However, each part must be placed perpendicular to the contact surface. This is accomplished by incorporating a pneumatic rotational capability into the end effector. Additionally, one degree of compliance was incorporated to fully seat the part on the surface. The bonding agent is allowed to make up the difference between the flat part surface and the convex surface of the motor.

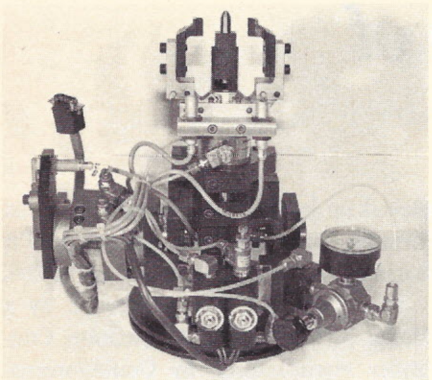

Photo 1. A specialized quick-change end effector with pneumatic rotational capability picks up a number of differently shaped parts, presents them for application of a bonding agent, and then places them perpendicular to the contact surface.

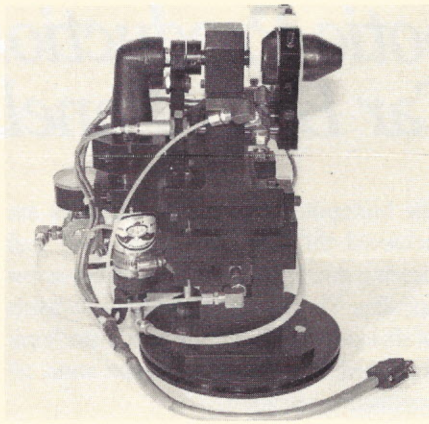

Photo 2. The quick-change end effector picks up another set of tooling to perform buffing operations on the rocket motor after the laser system has been removed and covered up to prevent contamination.

The quick-change feature is used again to pick up a buffing end effector (Photo 2) to perform buffing operations on the motor after the laser system has been removed and covered up to prevent contamination.

CONCLUSION

Ten end effectors of three different configurations were required for this assembly operation. Also required were a precision X-Y polar coordinate indexer, three degrees of compliance on some of the end effectors, and a laser system for positioning and for establishing a datum line for parts assembly to a rocket motor 8 ft in diameter, 40 ft long, and located somewhere in three-dimensional space.

George Montalbano is President of and Richard Schlais is Sales Manager for Montalbano Engineering.

Reader Feedback

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5	15	25
Excellent	Good	Fair

Robotic Production of Car Body Panels

Body panel stamping in automobile and truck manufacturing requires handling of unwieldy sheet metal, some pieces as long as 10 ft and weighing as much as 100 lbs. A 6-station line of robotic press loaders/unloaders with a load capacity of 180 lbs, including tooling, is turning out stamped body panels at the Chrysler Sterling Stamping Plant in Sterling Heights, Michigan. Prior to the August, 1985, automation of the line, the stamping presses had been fed manually. The Handler II-2, manufactured by Schuler, Inc. of Columbus, Ohio, is a third-generation press loader/unloader, designed to facilitate new or existing press lines.

The dual arm design with two axes of full programmability offers stroking distances of up to 100 in. horizontally and 30 in. vertically. Each axis is independently driven by a DC motor. Absolute positioning and accurate stroke repeatability for the horizontal and vertical carriages are achieved through the use of linear ball bearing guides and planetary roller screw spindles. The Sterling Heights line consists of six loaders/unloaders, one transfer/turnover device, and four transport units, all supplied by Schuler.

Sheet metal is manually fed at the blank pickup station at the top of the line and is picked up by the first loader, using pneumatically actuated grippers. The motion path of the panel typically follows an inverted U-profile, with easy program editing to accommodate various die heights, shapes, and sizes. A draw press in the second machine station makes the deepest parts of the body panel. The panel comes out of the press upside down. The unloader places it in the turnover/transfer device, which is capable of turning the panel 360 degrees by a pneumatically-activated turnover shuttle. The panel is picked up by the next loader and is fed through successive work stations until it is manually unloaded at the end of the line.

The Handler II-2 is controlled by a Model 3220 Flexible Automation Controller manufactured by Gould/International Cybernetics. The 3220 controls each loader/unloader and the transfer/turnover device, which has 6 axes of motion and is linked with a PLC. The transport devices share one axis of motion with the loaders/unloaders.

The Gould/ICC 3220 features DNP II (Direct Numerical Processing), a 16-bit microprocessor–based servo technology that is the key to the intelligent motion of the Handler II-2. DNP II calculates position and speed digitally, closing the position and velocity loops and updating at a rate of one millisecond. Analog tachometers, precision D to A converters, and virtually all other analog circuits and potentiometers can be eliminated.

DNP II technology allows for the synchronization of the Handler II-2 to the press via start/stop and speed modulation commands based on the encoded press crankshaft data. Actual axis positioning is programmable by jog-to-position and commands from a joystick controller using proprietary software written by Gould/International Cybernetics, or through serial links with a host computer. A complex motion profile can be achieved by profiling the axis cards with given points, creating a third-order fit between those points in real time.

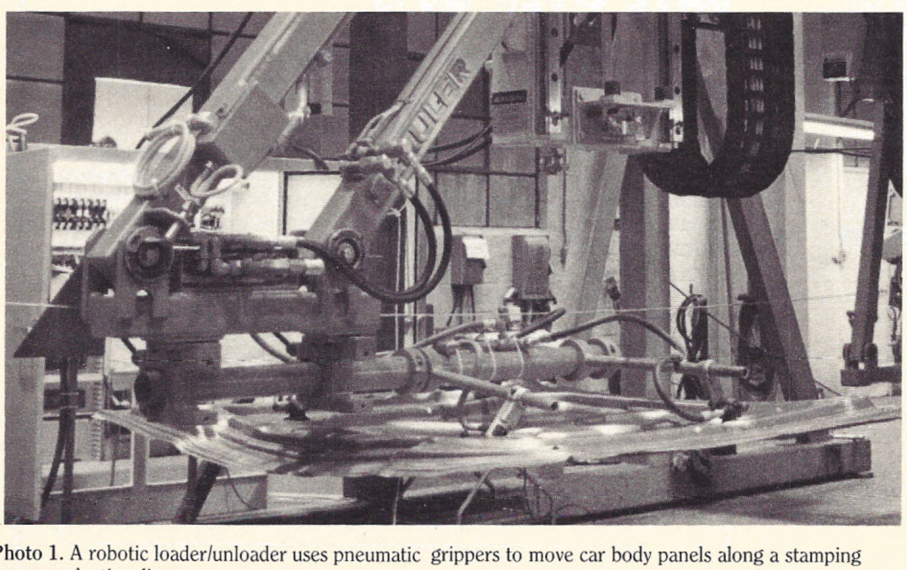

Photo 1. A robotic loader/unloader uses pneumatic grippers to move car body panels along a stamping press production line.

Gould/International Cybernetics
105 Delta Drive
Pittsburgh, PA 15238

Custom Robotic End Effectors—Two Examples

When a process is being automated for the first time, often an end effector is required that does not exist. Sometimes a standard gripper off the shelf can be modified to serve the purpose, but when the newly automated process calls for very highly specialized tooling, only highly specialized engineering will solve the problem. Automation Engineering is a small company that specializes in the design and fabrication of custom hard automation and robotic assembly and test systems. With the rise of industrial robotics, the firm has become specialists in custom robotic end effector development. Proper end effector design is the key to all successful robotic applications. The following is an account of two particularly challenging end-of-arm tooling problems.

The end effectors in Photos 1 and 2 were specifically designed for use on one robot doing insert molding. The tooling had to pick up threaded bushings (four per cycle) and insert them onto pins on a mold mounted in a Boy 50T injection molding machine. Care had to be taken when picking the bushings up so as not to damage their soft aluminum threads. Also, the bushings were presented to the robot for pickup via a precision singulating pin that was used to inspect their inside diameter prior to pickup and insertion. The very close tolerances between the singulating pin's outside diameter and the inside diameter of the bushings (± 0.0004 in.) eliminated the use of vacuum pickups and standard mechanical gripping devices.

Vacuum pickups would not work because of the close fit, and any misalignment would cause a window-locking condition that would strip off the bushings and break the vacuum. Mechanical fingers would not work for four reasons:

- They would damage the bushings' threads.
- They were too large, given an opening of only on the order of 8 in. through which to enter the mold, inspect for stuck bushings, and insert new bushings.
- Four mechanical gripping devices when combined with the other end effector components would be over the robot's payload weight restrictions.
- Because of the robot's accuracy (± 0.002 in.) and the very close tolerances between the i.d. of the bushings, the o.d. of the pins, and the

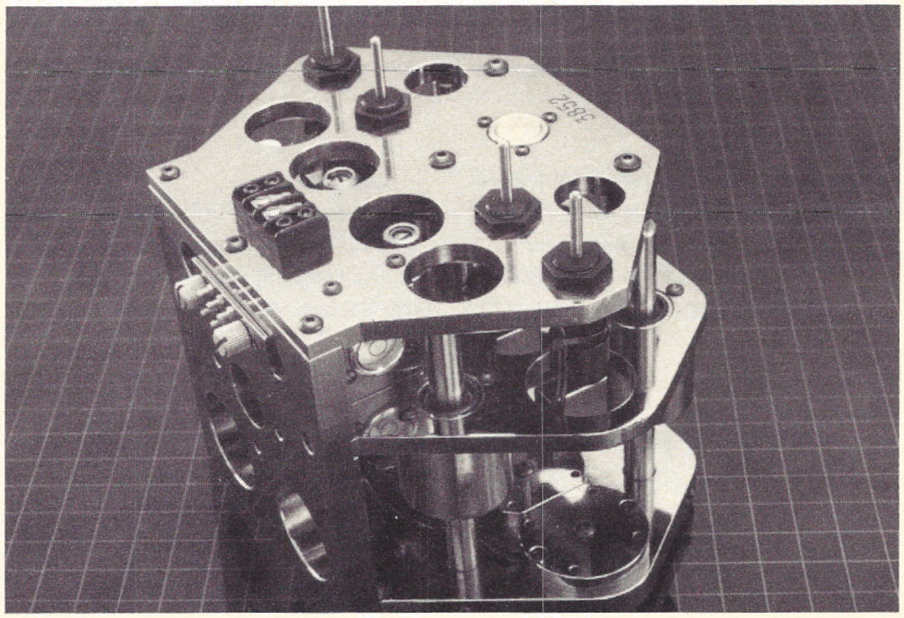

Photo 1. The four sensors (perpendicular to the faceplate) have built-in anti-window-locking features for probing cavities on an arc. They are designed to sense bushings stuck in an injection molding machine.

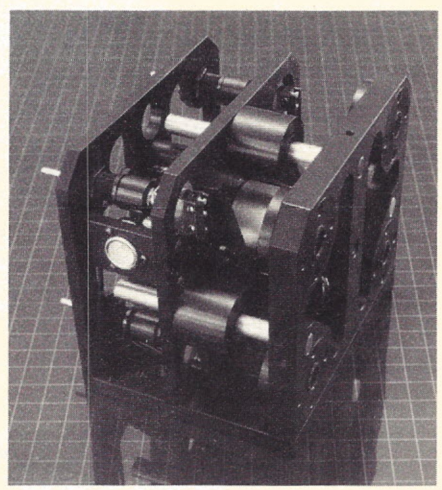

Photo 2. The four Grip-Tron gripping devices on the faceplate (right) are versatile, low profile, low mass, high gripping force, and self compliant.

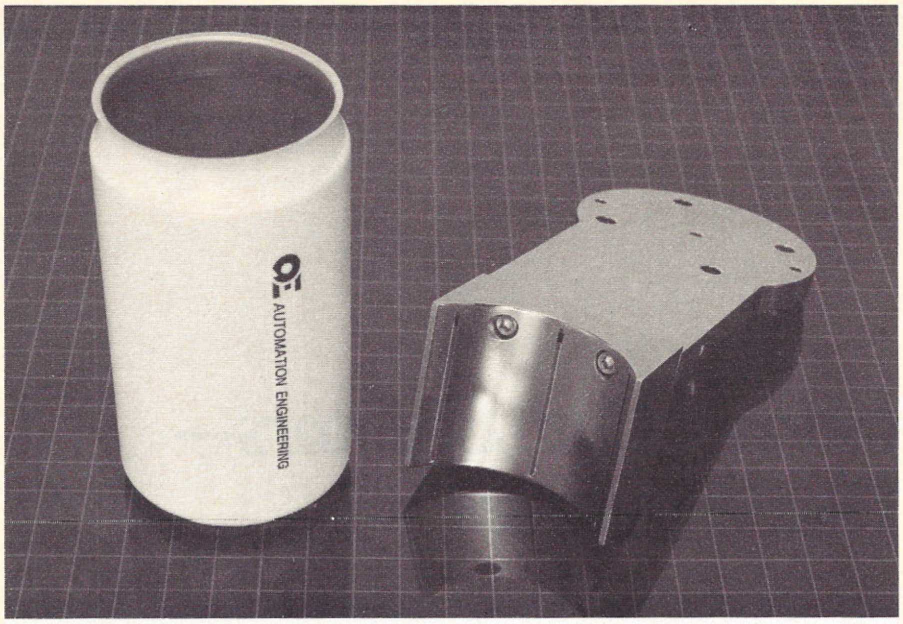

Photo 3. A vacuum pickup chuck takes thin-walled beverage cans off a production line without distorting the metal.

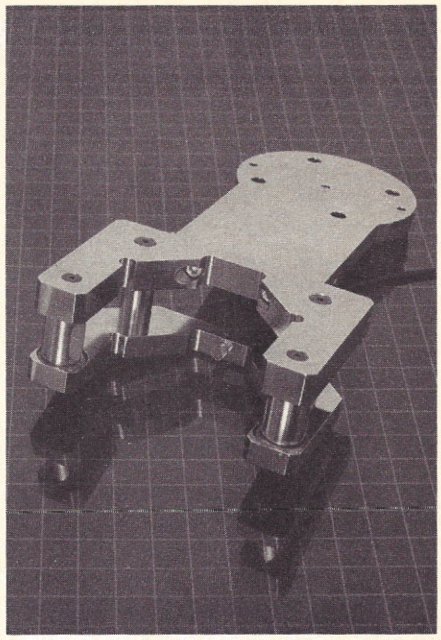

Photo 4. Another approach to robotic transfer of aluminum cans is a light touch mechanical gripper with pure gum diaphragm fingers.

location of the four pins on the mold, compliance had to be built into the gripping device to allow for any misalignment and keep the robot from jamming and the bushings from being damaged.

The robot used in this application was a GCA 200 V 5-axis machine. As it turned out, five were not enough axes to accomplish the task so a sixth axis was built into the end effector. The end effectors had to be made interchangeable. By interchanging the gripper end caps, end effectors, singulating pins, and programs (approximately 15 minute changeover time) one robot could be used to insert seven different styles of bushings onto seven different molds.

The end effectors shown in Photos 3 and 4 were developed for Seiko Instruments, U.S.A. for use in picking up unfinished aluminum beverage cans off a production line and presenting them to a vision inspection system developed by View Engineering. Two styles of end-of-arm tooling were developed for View Engineering's evaluation. The one in Photo 3 is a vacuum pickup chuck which has proven to work very well in lifting the cans without distorting or damaging their thin walls (0.004/0.005 in.) The second design is a light touch mechanical gripping device (Photo 4). This gripper has two pure gum rubber diaphragm fingers. When a low pressure air supply is applied, the fingers expand to push the cans into the V block of the end effector and hold the cans firmly in place without distortion or damage.

Automation Engineering
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San Bernardino, CA 92408

In The Robotics Age™

Edited by Stephanie vL Henkel

MARKET RESEARCH

U.S. industry is not competing effectively in the global market because of its failure to use available advanced manufacturing technologies, according to a new study released by the **Technology Management Center** in Philadelphia. The 18-month evaluation, prepared for the Department of Commerce and funded in part by the Office of Trade Adjustment Assistance, focused on three industries affected by import competition: machine tool, electronic components, and medical devices.

The most significant finding of the survey was that the majority of U.S. manufacturers ignore the argument that the new technologies produce goods of higher quality more quickly and cheaply than do older manufacturing methods. Despite the vast amount of publicity given automated manufacturing technologies, potential users remain puzzled about their use—even to the point of intimidation—and reluctant to implement them. The project researchers found this situation particularly ironic since most of the new technologies, such as NC equipment, robotics, and flexible manufacturing systems, were developed in this country.

In addition to the confusion factor, management was found to be overly concerned with short-term results and returns, and generally required a two-to-three year payback. In contrast, Japanese firms regard installing automated equipment an investment rather than a risk, and are more flexible about payback periods. Further, U.S. industry has generally been dedicated more to creating new product technologies than to improving production technologies; there are many instances of a prototype's being developed in this country only to be manufactured elsewhere because of our outdated production methods.

Even so, a large number of small and medium sized companies perceived themselves as using state-of-the-art technologies, an attitude evidenced in several cases where the researchers were required to sign confidentiality agreements to protect what the company being examined considered to be proprietary processes. (As it turned out, those firms exhibited some of the lowest levels of technology use.) Other firms believed that manually counting the number of parts in their storerooms twice annually and entering the data into a computer constituted a computerized inventory control system.

The solution is not simply to add computers and robots to existing production equipment. Many firms surveyed had implemented the new technologies without regard to their role in the overall manufacturing strategy, and the resulting islands of automation scattered about the shop floor were doing nothing to yield a better product. Advance planning is required to ensure systems integration.

Planning is lacking—but essential—in another area as well. Many small and medium sized companies do not understand that they are part of the

global market. They think of competition on a domestic level and fail to realize that a foreign firm might be making the same product at a lower cost and with better quality. When those companies do feel the effects of foreign competition, they tend to approach the government for assistance rather than try to upgrade their own performance. The report notes that none of the industry representatives interviewed has taken any anticipatory action to meet perceived import threats of the future.

SCIENCE & TECHNOLOGY

AMETEK/Offshore Research & Engineering Division has been contracted by the **Air Force Engineering and Services Center** at Tyndall AFB in Florida to design a full-scale air-mobile prototype of a remotely operated robotic firefighter system capable of replacing human firefighters in extremely hazardous environments. Operated by a firefighter stationed at a safe distance, the robot will contend with fires on munition-carrying aircraft. It is anticipated that the robot will be able to attack and extinguish both external and internal fires and to cool ordnance, thus preventing explosions.

Martin Marietta Aerospace (Baltimore Division) has set up a research associate program with the **National Bureau of Standards** to study possible applications of the NBS's Automated Manufacturing Research Facility to military logistic systems and robot vehicles for battlefield use. John Wilkes of MMA will work with AMRF researchers to investigate NBS's technology for integrating modular control systems, and in particular the NBS robot control system, which emphasizes real-time control through extensive use of sensory feedback.

Adaptive Technologies, Inc. has received a $250,000 subcontract on a $½ million Small Business Innovation Research Grant awarded to **Athtec Systems, Inc.** by the **National Institutes of Health** to develop a strength training robot for rehabilitative and athletic applications. The robot will use a 6-D force sensor to accurately measure and control loads applied to human limbs. The system will allow 3-D training, an advance over the 2-D approaches in current use. In addition, the new system will provide therapy both more extensive and at a lower cost than has thus far been available.

CORPORATE NEWS

► **Scovill Inc.**, a subsidiary of First City Industries, has sold its **Schrader Bellows** subsidiary to **Parker Hannifin** for $77.5 million in cash. A Scovill spokesman said the proceeds of

the sale would be used to reduce long-term debt and related interest charges. It was also noted that selling Schrader Bellows was expected to improve Scovill's domestic cash flow by reducing the company's exposure to certain foreign governments and their currency regulations that could limit the repatriation of funds. Schrader Bellows makes pneumatic control products for industrial automation.

► **XTAL Corporation** has been awarded equipment contracts for its factory automation system, Factorynet®, by the **Army,** the **Navy**, and the **Air Force**. The contracts, worth $292,000, will support networking CAD/CAM, machine tools, and coordinate measurement machines among local or remote defense installations and their prime subcontractors who supply weapons systems to the Defense Department.

► **GMF Robotics** and **Applied Robotics** have entered into a three-year OEM agreement whereby GMF will market Applied's line of robotic hand exchange systems and end effectors as complete GMF integrated products. The line includes standard mechanical, vacuum, and magnetic grippers that mount on the hand exchanger or directly to the robot tool mounting face plate.

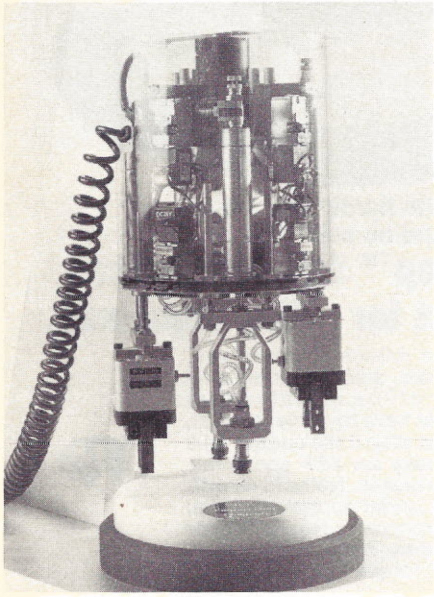
► **CR Technology, Inc.**, a manufacturer of machine vision based automated test equipment, has moved to new facilities in Laguna Hills, California. A company spokesman said the larger quarters reflected an increased market acceptance of automated final test and inspection via machine vision and other computer controlled capabilities.

► Over 30,000 participants at more than 400 locations were counted as having taken part in a satellite symposium on artificial intelligence sponsored by **Texas Instruments** on November 14, 1985, making it the largest videoconference ever held. The event was organized by TI's Data Systems Group and included among its attendees academic, industrial, and business organizations. A question and answer session provided direct interaction with the panelists: Bruce G. Buchanan and Edward A. Feigenbaum of Stanford, Mark A. Fox of Carnegie-Mellon, and Randall Davis of MIT's Sloan School of Management. Harry Tennant of TI's computer science lab chaired the conference.

CALL FOR PAPERS

The **Society of Photo Optical Engineers** will sponsor five related conferences the week of October 26–31, 1986, in Cambridge, Massachusetts. Topics to be addressed are: Intelligent Robots and Computer Vision; Mobile Robots; Optics, Illumination, and Image Sensing; Automatic Inspection and Measurement; and Space Station Automation. The due date for abstracts is April 15, 1986. Papers should be submitted to Dr. David Casasent, Department of Electrical and Computer Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213. Dr. Casasent is the general conference chairman.

End Effectors Product Guide



IFT Engineering Company

The GMGK-1 is a multi-task end effector capable of holding up to four different sized and shaped parts and thus reduce robot cycle time. It contains eight solenoid valves, up to eight magnetic reed switches, and is prewired for easy interface with the robot controller. Four of the solenoids are dedicated to a vertical stroke of up to 1.5 in. The system can use air and vacuum grippers, sensors, and other assembly tools.

Specifications include: 5.5 in. height; 5.25 in. diameter; 4.5 lbs. weight; 24 VDC and compressed air power source; 80–100 psi air pressure; and specifiable vertical stroke.

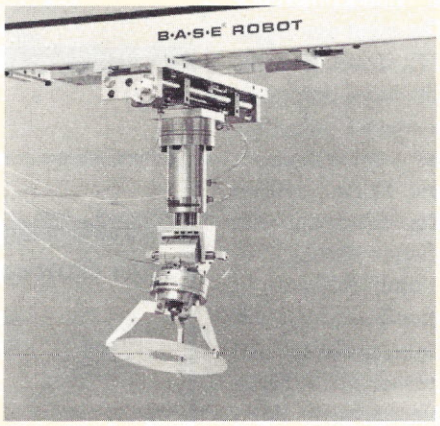
For more information, contact: Gregory A. Kaplan, Vice President, IFT Engineering Co., 706 Marple Woods Dr., Springfield, PA 19064, telephone (215) 544-2546. Circle 70

Jergens, Inc.

The New-Mat, a self locking robotic gripper for light assembly and material handling, features fingers that hold their positions despite accidental loss of air or oil pressure. The double action piston that operates the fingers assures greater return stroke control than spring return pistons. The fingers open 180 degrees and can be adjusted to limit jaw angle. In the open position, the gripper completely clears the workpiece, allowing it to be repositioned or moved without moving the gripper.

The New-Mat is available in three sizes with rated loads from 4 to 24 lbs. All faces of the hardened anodized aluminum body are machined. Either air or oil service can be specified.

For more information, contact: Jergens, Inc., 19520 Nottingham Rd., Cleveland, OH 44110, telephone (216) 486-2100. Circle 71

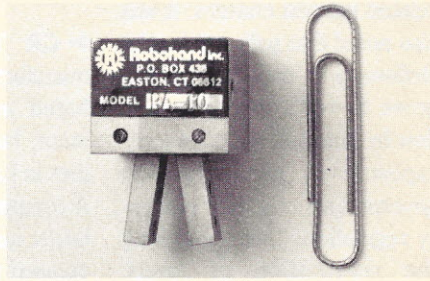


Mack Corporation

Mack has added to its large line of robotic end effectors a line of two- and three-finger grippers designed to hold 5-1/4 in. rigid disks. The two-finger grippers simulate the motions of the thumb and index finger for grasping the disk by the edge for reaching into close spaces. The third finger permits the gripper to hold the disk by its edge from the face side.

All units operate on the principle of a double acting cylinder controlled by a four-way valve circuit. Fluid pressure opens or closes the fingers for positive operation. Fittings are supplied for 1/8 in. i.d. flexible tubing.

For more information, contact: Marketing Dept., Mack Corporation, 3695 E. Industrial Dr., PO Box 1756, Flagstaff, AZ 86002, telephone (602) 526-1120. Circle 72



Robohand, Inc.

The RA-10 angular motion gripper from Robohand is a 1 oz. unit that provides a gripping force of 10 lbs. The gripper measures 1-7/16 in. high, 1 in. wide, and 1 in. in depth. The unit's fingers are 5/8 in. long.

Being one of the smallest of such devices on the market, the angular motion gripper is appropriate for electronic and other small parts assembly applications.

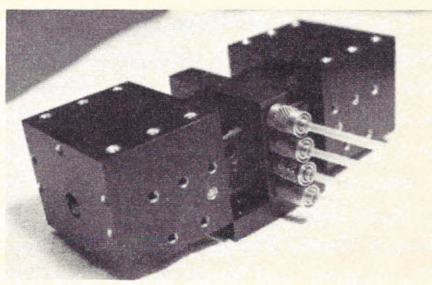
For more information, contact: Nicky Borcea, President, Robohand, Inc., PO Box 438, Easton, CT 06612, telephone (203) 374-6063. Circle 73

Mecanotron Corporation

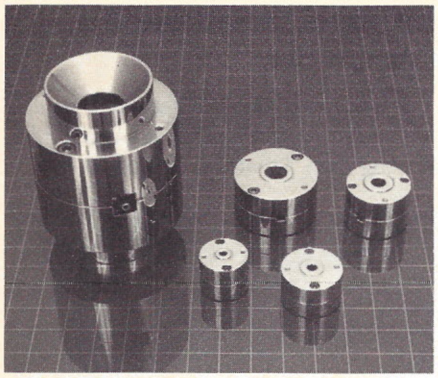
Mecanotron's FLAT PC™ (Flat Linear Actuator True Parallel Gripper) is a low profile servo end effector that can be used alone or with several units bolted to a manifold to grip a long part or several parts simultaneously. The true parallel finger mounts are designed to hold a variety of finger shapes to handle inside diameter, outside diameter, odd-shaped parts and components, pick and place, palletizing/depalletizing, machine load/unload, and assembly. These fingers can move independently or at the same time.

The end effector may have a sensor interface for sensing part presence. Quick-change finger capability is available.

For more information, contact: Mecanotron Corporation, 1728 N. Second St., Minneapolis, MN 55411, telephone (612) 521-8559. Circle 74



End Effectors Product Guide



Automation Engineering

The Grip-Tron™ from Automation Engineering is a versatile, low profile, low mass, high gripping force, self compliant gripping device. Its unique design allows a robot to grip objects of various shapes and sizes without damaging painted or highly finished surfaces.

The gripper is supplied with tooling holes at both ends that can be machined to the user's desired dimension(s) to accomodate the part to be gripped. Grip-Tron is available off-the-shelf in four sizes with tooling holes from 0.06 in. to 1 in. but can be custom designed and fabricated for objects up to 12 in. in diameter.

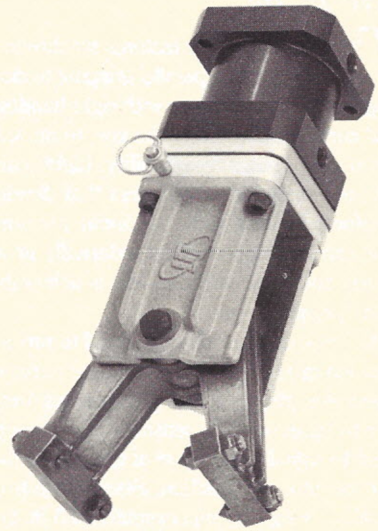
For more information, contact: Automation Engineering, 1814 Commercenter West, San Bernardino, CA 92408, telephone (714) 889-2664. Circle 75

I.S.I. Manufacturing, Inc.

New additions to I.S.I.'s product line of over 50 styles of vacuum and pneumatic end effectors are the LPAC 200 and 250 profile, light weight, pneumatic gripper head cylinders. The cylinders are built with a T-slotted piston rod end. An optional quick-change adapter permits a handling system to host an unlimited number of parts by removing the quick change release pin.

The assembly, designed for rear flange mounting, is built of machined tool quality construction with hardened and ground pins. Forged aluminum side plates are also available for applications where weight is a critical factor. The LPAC 200, when fitted with a mini head weighs 4 lb. 20 oz., and the standard size LPAC 250 with head weighs 10.5 lbs.

For more information, contact: I.S.I. Manufacturing, Inc., 31915 Groesbeck Highway, PO Box 220, Fraser, MI 48026, telephone (313) 294-9500. Circle 76

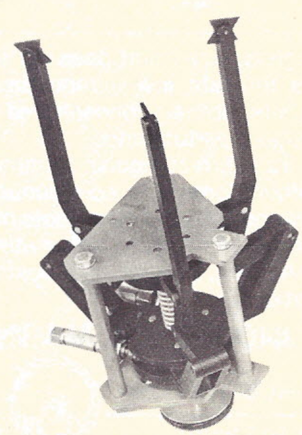


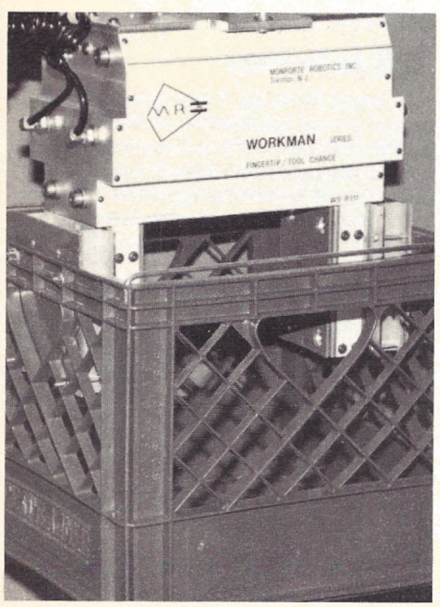
Robo-Tech Systems

Three compliant grippers are available from Robo-Tech: the Model 10 has a 20 lb. payload and has an aluminum frame and components; the Model 20 has a 20–40 lb. payload and is made of aluminum and steel; and the Model 30 can carry 40–60 lbs and is of hardened steel. The three-jaw grippers have a pattern changing time of 0.3 sec. for air and 0.5 sec. for electric actuation. Both can take place while the robot arm is moving between points during the cycle. The gripper can grasp and manipulate tools with ordinary handles. Strain gauges can be attached to each of the three fingers and other transducers can be used for force feedback.

Gripper weights range from 2.5 lbs to 20 lbs. Payload sizes range from a wrap of 3 to 9 in. diameter, depending on the gripping method (wrap, three-jaw, tip, and spread).

For more information, contact: Robo-Tech Systems, 77 E. Wilson Bridge Rd., Suite 207, Worthington, OH 43085, telephone (614) 431-9418. Circle 77





Monforte Robotics, Inc.

The Workman series of end effectors features exchangable adapter keys that rapidly execute a fingertip or tool change and eliminate the process of changing entire end effectors for each application. The Workman robot hand is capable of performing a variety of tasks in one cell, including palletizing, mechanical assemblies, multi-part acquisition, material handling, and machine loading and unloading. The end effector has a base weight of 22 lbs, 0–300 lbs payload, 7 in. true parallel stroke, 850 lbs maximum gripping force, and six distinct modes of pickup: inner/outer diameter finger grasps, inner/outer fingertip change, and inner/outer tool change.

For more information, contact: Monforte Robotics, Inc., 2333 Whitehorse-Mercerville Rd., Trenton, NJ 08619, telephone (609) 586-5094. Circle 78

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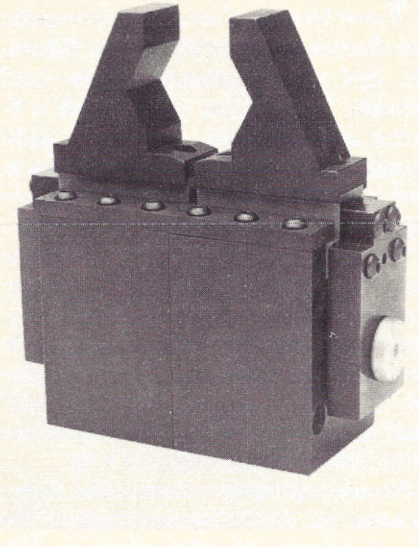
Zaytran Inc.

The GP gripper line features synchronous jaw action and a parallel gripping motion. A high helix control screw with right hand/left hand configuration forces the jaws to move in unison and assures repeatability. Light, compact jaws employ dual cylinders that develop a uniform holding force via input pressure. Parts can be gripped either externally or internally and total holding force is achievable in any gripping position.

The basic design can be adapted to provide extended grippers for handling wide parts, or long-stroke grippers for irregular shapes. Proximity switches or other sensing devices can be added to signal completion of gripping action or to monitor jaw position. Sizes range from the micro, weighing approximately 0.5 lb. and exerting 10 lbs of closing force at 100 psi, up to a 23 lb. unit capable of 400 lbs of force at 100 psi.

For more information, contact: Zaytran Inc., PO Box 566, Elyria, OH 44036, telephone (216) 324-2814.

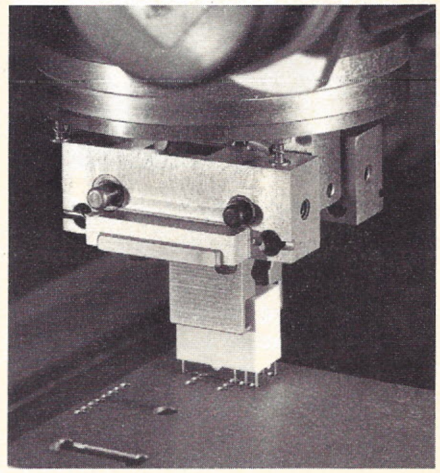


Circle 79

Universal Instruments Corporation

The Model 6511A Vari-Cell® robotic assembly system offers as an option the Floating Hand. The device can float up to 0.30

Circle 80



End Effectors Product Guide

in. in both the X and Y directions, enabling the gripper tooling to pick up components whose leads and bodies are out of registration.

When there is a box relay where lead-to-lead dimensions are measured closer than lead-to-body dimensions, the Vari-Cell lifts a component by its body and transfers it to a gauge block with tapered holes. When it reaches the block, the grippers are released while enough vertical pressure is placed on the component to correctly reorient it. At the same time, the leads are forced to conform to the hole configuration in the gauge. Finally, the Floating Hand conforms to the body's new orientation and locks in place and the Vari-Cell "knows" the location of the leads.

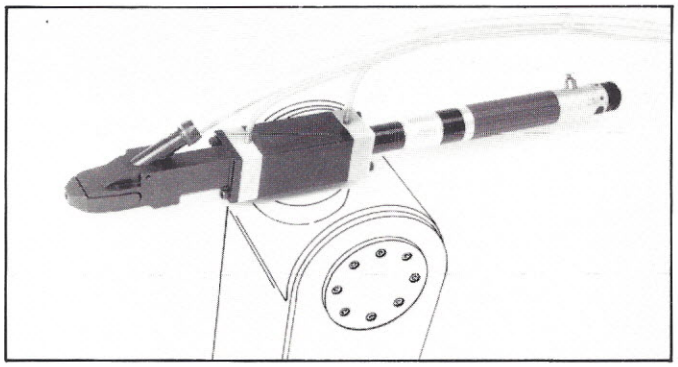
For more information, contact: Dennis S. Horne, Marketing Services, Universal Instruments Corporation, Box 825, Binghamton, NY 13902-0825, telephone (607) 775-1102.

Clyde Corporation

A self-feeding fastener feed and drive unit to interface with robotic assembly equipment has been introduced by Clyde Corporation. Designed as an end-of-arm tool for robots, the feed and drive unit consists of a nose piece assembly, drive spindle with drive or socket, and a flexible feed tube connected to a feeder. The unit may be adapted to any pneumatic or electric tool with torque control or torque transducers. Optional controls, including depth sensors, may be incorporated.

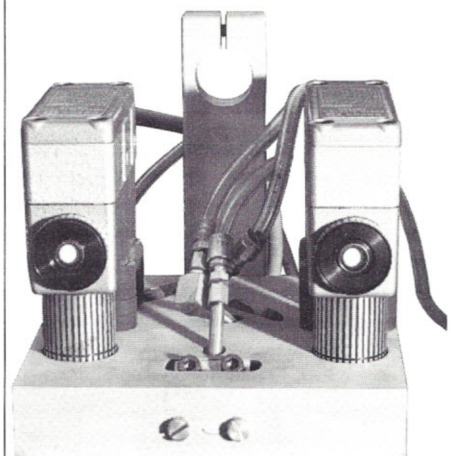
During the sequence of operation, the robot arm carries the nose to the workpiece and places an exposed screw into position. A four-way valve is energized, moving the drive spindle forward and driving the screw into the workpiece to the proper depth or torque. When the spindle is fully retracted, a meter escapement on the feeder is activated to feed a new screw. Withdrawing the nose before the spindle is retracted provides an automatic self-clearing function.

For more information, contact: M.A. MacDonald, President, Clyde Corporation, 2281 Star Court, Auburn Heights, MI 48057, telephone (313) 852-7770. Circle 81

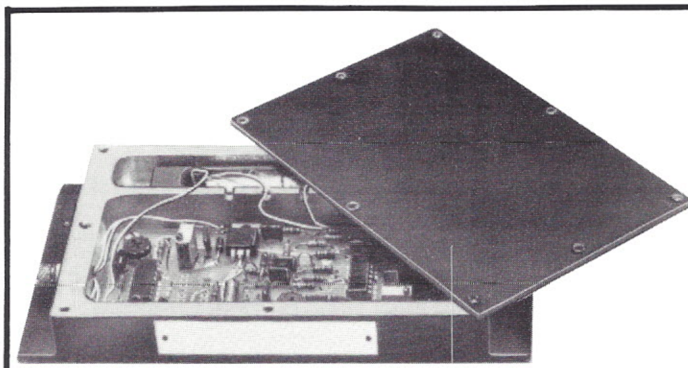


H.R.C. Consultants

The H.R.C. 1165 was designed to pick and place fiber glass filter elements. It has also



Classified Advertising



found application in robotic sewing machine operations, where the sensors are said to function as safety features. The end effector works on the principle of internal tension, using pneumatically activated probes of 10-micron hardened steel that go into the filter elements, a method described as superior to vacuum or gripping devices for moving the delicate filters. Mounted on the end effector, but isolated from it to eliminate vibration, are two reference beam color mark sensors. The reference beam and the object beam are color sensitive and can recognize red, blue, beige, and yellow. The information advises the end effector as to the direction from which the probes should approach the filter elements. The downstream control architecture places the sensor as close to the workpiece as possible so that the machine views reality; it is therefore not necessary to program the system for every potential situation.

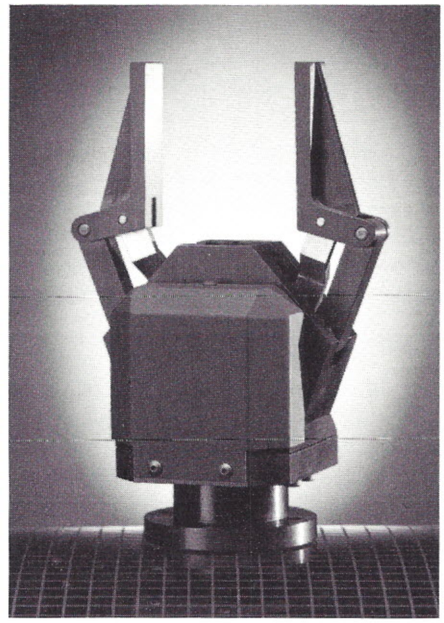
For more information, contact: R.J. Walsh, H.R.C. Consultants, PO Box 620, Wheaton, IL 60189, telephone (312) 690-7349.
Circle 82

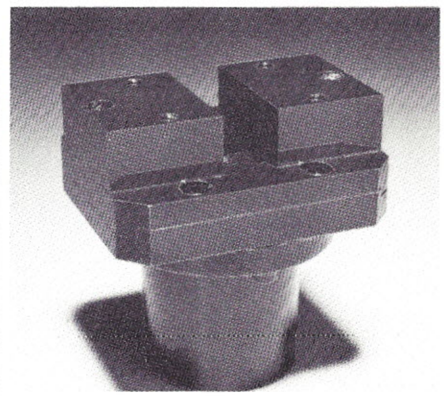
TeleOperator Systems Corporation

TeleOperator Systems Corp. has developed the EP 100/30 series line of standard, off-the-shelf end effectors that can grasp objects of diverse size, weight, and fragility to accommodate changing application requirements within the same program cycle. They are adaptable to almost any robot controller and allow the programming of closing force, closing position, and speed. They also will accommodate a large number of instrumentation options that provide the user with operational flexibility.

The activation of the EP 100/30 series is through low inertia, rare earth DC servo motors that provide an opening range of up to 4 in. and a maximum force of 66 lbs. The end effector weighs 3.5 lbs. with standard finger configuration.

For more information, contact: Carl Flatau, President, TeleOperator Systems Corp., 45 Knickerbocker Ave., Bohemia, NY 11716, telephone (516) 567-8787. Circle 83





Barry Wright Corporation

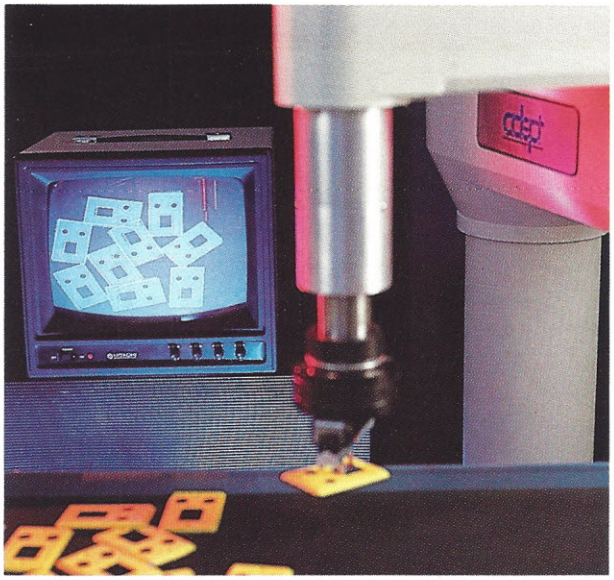
The PJS-80 gripper is a new parallel action pickup tool for automatic and robotic assembly. It is double acting and features constant gripping force throughout the full finger travel. It is designed to fit into a modified Astek Accommodator remote center compliance Model AST-100.

The gripper has a dovetail slide and has 0.6 in. of finger travel. Tapped holes are provided so that custom jaws can be attached. Custom fingers are also available.

Other specifications include: 80 lb. gripping force through full slide travel, operating pressure of 50–120 psi, and maximum finger movement of 0.6 in.

For more information, contact: Barry Wright Corporation, 700 Pleasant St., Watertown, MA 02172, telephone (617) 924-2929. Circle 84

Why robot vision doesn't have to slow a robot down.



Most robot vision systems simply aren't good communicators. They load a robot down with more data than it can handle . . . and transmit that data over slow serial or I/O ports. So while they might "see" in real time, they can't make the robot react in real time.

AdeptVision™ can. . . and does.

Real time vision, real time reaction.

AdeptVision communicates with the robot controller quickly because it communicates directly . . . in the same language . . . without any of the integrating hardware and software that slows other systems down and drives installation costs up.

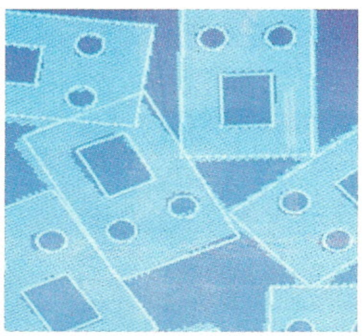
In other words, AdeptVision comes fully integrated with the Adept robot system, and the result is sheer speed. In both its area and moving line versions, AdeptVision identifies and locates up to six parts per second — and communicates the information fast enough to guide the robot's path in real time.

Simplicity plus brainpower.

Most vision systems require special software for each part they handle. And most vision companies don't tell you that. This can burn up several man-months of an expensive programmer's time and delay your start-up significantly.

AdeptVision requires no part-specific software. It's ready to go the day you install it and requires only about 15 minutes of training per part.

What's more, because AdeptVision identifies significant part features instead of the entire part area, it accomplishes more with less raw data. And then turns it into real time robot guidance information with powerful 68000 processors.



AdeptVision™ quickly identifies randomly oriented, touching, or overlapping parts.

Touching and overlapping parts.

Most vision systems can't identify parts the way they're presented in real life: randomly oriented, touching, or even overlapping. AdeptVision can, because its unique algorithms work with part features instead of areas.

This flexible parts presentation ability can save you a fortune in hard tooling costs now . . . and later on when you change product mix or design.

Seeing is believing.

We'd like to show you AdeptVision in action . . . at an Adept-equipped systems integrator near you. Just give us a call, and we'll make the arrangements. In the meantime, we'll mail you all the details. Just contact Adept Technology, Inc., 1212 Bordeaux Drive, Sunnyvale, California 94089. Phone: (408) 747-0111. TELEX: 171942.

adept™

adept technology, inc.

Robots that work.

Circle 57